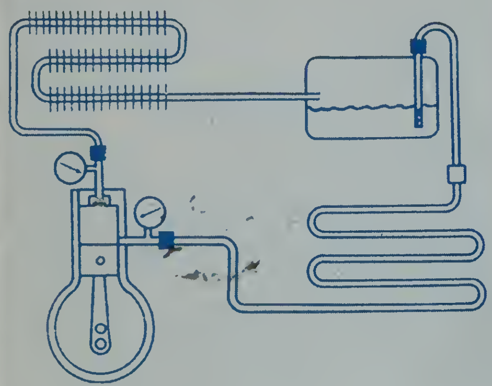
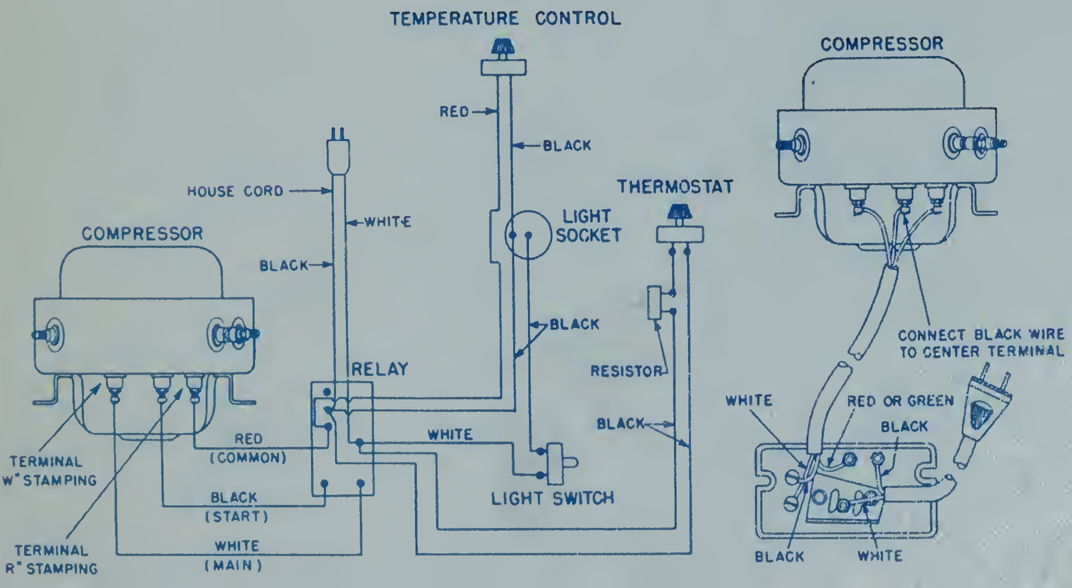


practical application
of **refrigeration**
in all of its branches

Modern Refrigeration and air conditioning

ALTHOUSE AND TURNQUIST



Modern Refrigeration *and air conditioning*

BY

ANDREW D. ALTHOUSE, B.S., (M.E.), M.A.

Assistant Director
Vocational Education Department
Detroit Public Schools
Member, American Society
of
Refrigerating Engineers

AND

CARL H. TURNQUIST, B.S., (M.E.), M.A.

Head of the Refrigeration Department
Cass Technical High School
Detroit, Michigan
Associate Member, American Society
of
Refrigerating Engineers

CHICAGO
THE GOODHEART-WILLCOX COMPANY, INC.
Publishers

Printed in the United States of America

Library of Congress Catalog
Card Number: 60-6022

INTRODUCTION

MODERN REFRIGERATION and AIR CONDITIONING covers the practical application of refrigeration in all of its branches--Domestic, Commercial, Frozen Food Refrigerators, Air Conditioning, Heat Pumps, etc.

MODERN REFRIGERATION and AIR CONDITIONING teaches refrigeration and air conditioning principles--the foundation on which a thorough knowledge of these important subjects is based.

Beginners and apprentices in refrigeration and air conditioning will find this book a real aid to getting started on a pleasant and profitable career. Experienced servicemen will find it invaluable as a guide, and a reference.

Andrew D. Althouse

Carl H. Turnquist

ACKNOWLEDGMENTS

The production of a book of this nature would not be possible without the co-operation of the Refrigeration and Air Conditioning Industry.

In preparing the manuscript for MODERN REFRIGERATION and AIR CONDITIONING, the industry has been most co-operative. The authors acknowledge the co-operation of these companies with great appreciation:

Aerovox Corp.
Airo Supply Co.
Airserco Mfg. Co., Inc.
Airtemp Div. Chrysler Corp.
Alco Valve Co.
Allin Mfg. Co.
The American Brass Co.
Kelvinator Div., American Motors Corp.
American Potash & Chemicals Corp.
American Society of Heating and Air Conditioning Engineers
American Society of Refrigerating Engineers
Aminco Refrigeration Products Co.
Anemostat Corporation of America
Ansul Chemical Co.
A-P Controls Corp.
Automatic Controls Corp.
Avco Mfg. Corp., Crosley Div.
Baltimore Aircoil Co., Inc.
Barostat Co.
Friez Instrument Div, Bendix Aviation Corp.
Ben-Hur Mfg. Co.
Black, Sivalls & Bryson Inc.
Borg Warner Corp., Norge Sales Div.
The Bristol Co.
Brunner Mfg. Co.
Bush Mfg. Co.
Cadillac Motor Car Div., General Motors Corp.
Carrier Corp
Century Electric Mfg. Co.
Chicago Seal Co.
Chrysler Corp., Dodge Div.
Clesco Mfg. Div., Cleveland Sales Co.
The Cleveland Twist Drill Co.
W. B. Conner Engr. Corp.
The Coolerator Co.
Copeland Refrigeration Corp.
Cutler-Hammer Inc.
Detroit Controls Corp.
Dole Refrigerating Co.
Dry Zero Corp.
Duro Metal Products Co.
F. W. Dwyer Mfg. Co.
The Ebco Mfg. Co.
The Electric Auto-Lite Co.
The Emerson Electric Mfg. Co.
Esco Cabinet Co.
Faraday Refrigerator Corp.
Fedders-Quigan Corp.
Filtrine Mfg. Co.
Ford Motor Co.
Franklin Mfg. Co.
Frigidaire Div., General Motors Corp.
The Fusite Corp.
General Controls
General Electric Co.
Pontiac Motor Div., General Motors Corp.
General Refrigeration Sales Corp.
Gibson Refrigerator Co.
Gilbert & Barker Mfg. Co.
Glascock Bros. Mfg. Co.
The Goodyear Tire & Rubber Co.,Inc.
Greenfield Tap & Die Corp.
Henry Valve Co.
Halstead & Mitchell
Hotpoint Corp.
Handy & Harman
Houdaile-Hershey Corp.
Illinois Testing Laboratories, Inc.
The Imperial Prass Mfg. Co.
International Harvester Co.
Iron Fireman Mfg. Co.
The Jaqua Advertising Co.
Jarrow Products Inc.
Johnston Refrigeration Service
D. Kay Mfg. Co.
Kerotest Mfg. Co.
E.I. Du Pont De Nemours & Co., Kinetic Chemicals Div.
Koch Refrigerators, Inc.
Kold-Hold Mfg. Co.
Lando Advertising Agency
Lehigh Mfg. Co.
Linde Air Products Co.
Lynch Corp.
Marsh Instrument Co.
Maurey Mfg. Co.
McCall Refrigerator Corp.
The McCarthy Co.
McCord Radiator & Mfg. Co.
McCray Refrigerator Co., Inc.
McQuay Inc.
The McIntire Co.
Mechanical Refrigeration Enterprises
Mills Industries Inc.
Montgomery Ward & Co.
Mueller Brass Co.
Nash Div., American Motor Corp.
National Cooler Corp.
Nicholson File Co.
Owens-Corning Fiberglas Corp.
Paragon Electric Co.
Peerless of America Inc.
Penn Controls, Inc.
Perfection Stove Co.,Inc.
Philco Corp.
Pittsburgh Plate Glass Co.
Pyramid Instrument Corp.
Ranco Inc.
Redmond Co., Inc.
Refrigeration Engineering, Inc.
Remington Corp.
Remco Inc.
Republic Steel Corp.
Resistoflex Corp.
Rotary Seal Co.
Ryan Electronics, Inc.
Schaefer Brush Mfg. Co., Inc.
Wm. Schaller Co., Inc.
Seeger Refrigerator Co.
Servel Inc.
Simpson Electric Co.
Snap-on Tools Corp.
South Bend Lathe Works
Spencer Thermustat Div.
Sporlan Valve Co.
Standard Refrigeration Co.
Stevens Appliance Truck Co.
Stewart-Warner Corp.
Studebaker-Packard Corp.
Sundstrand Hydraulic Div.
Sweden Freezer
Taylor Instrument Companies
Tecumseh Products Co.
Temprite Products Corp.
Tenney Engineering, Inc.
Timken Silent Automatic Div., Scaife Co.
The Torrington Mfg. Co.
Tranter Mfg. Inc.
Tubing Appliance Co., Inc.
Tyler Refrigeration Corp.
Ultra-Violet Products, Inc.
Wabash Corp.
Wagner Electric Corp.
The Warren Co.
Webster Electric Co.
Westinghouse Electric Corp.
White-Rodgers Electric Co.
Williams Oil-O-Matic Heating Corp.
Wilson Refrigeration Inc.
York Corp.

CONTENTS

Chapter 1

FUNDAMENTALS OF REFRIGERATION

1-1. HISTORY OF REFRIGERATION

As far back as history can be traced, snow, ice, and cold water have aided mankind in keeping his food supply in good condition. Even today in some areas porous vessels containing water are used to cool beverages and foods. Also, during the warmer months, food is kept in deep caves or just over the surface of water in deep wells.

Refrigeration, the industry of preserving food by cold, first became of commercial importance during the 18th century, when ice formed during the winter on the surface of lakes and ponds was cut and stored in insulated store rooms to be used during the summer. This practice was followed by shipping ice from the colder climates to the hotter zones, but this did not turn out successfully. The use of natural ice made necessary the building of insulated containers or ice boxes. These first appeared on a large scale during the 19th century.

Ice was first made artificially in about 1820, but it was not until 1834 that this was done successfully. Jacob Perkins, an American engineer, was the inventor of this apparatus, which was the forerunner of our modern compression systems. In 1855 a German produced the first absorption type of refrigerating mechanism, although Michael Faraday discovered the principle of the absorption type in 1824.

The production of artificial ice made very little progress until shortly after 1890. During that year a shortage of natural ice gave impetus to the mechanical ice-making industry. Since 1890, the growth of mechanical refrigeration in the United States has been phenomenal.

Domestic refrigeration first made its appearance about 1910. J. M. Larsen produced a manually operated household machine in 1913. It was not until 1918 that the first automatic refrigerator was available on the American market (the Kelvinator). The Kelvinator Company sold its first machine in 1918. Kelvinator sold sixty-seven machines that year. Between 1918 and 1920 two hundred units were sold. Freezing of meats was first studied in 1923 and was the origin of the frozen foods industry. The General Electric Monitor Top appeared in 1926 after eleven years of experimenting. The Monitor Top was the first of the "sealed" or hermetic automatic refrigerating units. Beginning with 1920, domestic refrigeration became one of our important industries. The Electrolux, which is an automatic domestic absorption unit, appeared on the American market in 1927. The use of automatic refrigeration units for comfort cooling appeared on the market in 1927.

1-2. SCOPE OF MECHANICAL REFRIGERATION

Mechanical Refrigeration is used for domestic refrigeration, commercial refrigeration, air conditioning, comfort cooling, dehumidifying, freezing foods, cooling in manufacturing processes, and numerous other applications.

1-3. HEAT

Heat is molecular motion. All substances are made up of tiny molecules which are in a state of rapid motion (vibration). As the temperature of a substance is increased the motion increases and as the temperature decreases, the molecules motion decreases. If all heat is extracted (absolute zero) from a substance, the molecular motion will cease.

1-4. COLD

Cold is a relative term used to denote a low temperature. Cold is not something which is produced, but rather heat is extracted and the resulting condition is called cold. A refrigerator produces a condition called "cold" by the process of extracting heat from the interior of the refrigerator cabinet. The refrigerator does not destroy the heat, but rather pumps the heat from the inside of the box to the outside. Heat and cold are opposite ends of the same thing. It may be pointed out here that heat cannot travel from a cold body to a hot body, but always travels from the body of a higher temperature to a colder one. (Second law of Thermodynamics.)

1-5. HOW COLD PRESERVES FOOD

As the molecules move slower, there is an important effect on the bacteria that are present in most foods. Cold, or low temperatures, slows up the growth of these bacteria and foods do not spoil as fast. Slowing the movement or cooling of the molecules tends to make all organisms more sluggish. Spoiling of food is actually the growth of bacteria in the food. If these bacteria can be kept from increasing, the food will be edible for a longer period of time. Since most foods have a considerable water content, the food must be kept just above freezing temperatures.

If food is frozen slowly at near the freezing temperature the ice crystals formed are large and their growth ruptures the food tissues. When the food melts it spoils rapidly and its appearance and taste are ruined. Fast freezing at very low temperatures forms small crystals and the food tissues are not injured.

1-6. REMOVING HEAT

Heat always flows from hot to cold, that is from higher temperatures to lower temperatures. Faster moving molecules impart some of their energy to slower moving molecules. Therefore, the faster molecule slows a little and the slower one moves a little faster. Sometimes, however, the molecules instead of moving slower or faster, change their shape. The change in shape is caused by one or more of the atoms in the molecules shifting to a different position and the molecule will change from a gas to a liquid, or vice versa.

1-7. BASIS OF MECHANICAL REFRIGERATION

In order to understand the operation of the mechanical refrigerator, it is important to understand the

physical and thermal properties of the mechanisms and of the substances used to produce cold. A study of elementary physics is needed in order that all the explanations may be well understood. A leaking canoe can be kept afloat by means of bailing the craft with a sponge. If the sponge is used to soak up the water and is then squeezed over the side and the process repeated the canoe will be freed from the water. The water has not been destroyed, but merely conveyed from inside the canoe into the lake.

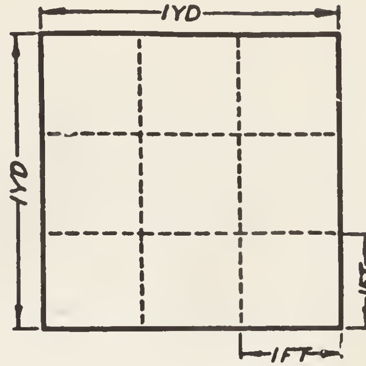
A refrigerator operates in a similar manner. A substance (refrigerant) is piped into the refrigerator in such a way that it soaks up heat from the box and is then passed to the outside of the box where the heat is squeezed out. The repetition of this cycle on the part of the refrigerant produces a condition in the box called cold. It should be noted that some of the heat has been removed, not all of it. Service managers of refrigerator companies prefer service and installation mechanics who are well grounded in the essential principles of physics as it pertains to refrigeration.

1-8. DIMENSIONS

All measurement of dimensions in this text are based on the English units such as, inches, feet, and yards. One must be able to accurately measure cabinet sizes and volumes. One must be able to measure tubing sizes, piston, cylinder, journal sizes and the like to very accurate dimensions.

12 inches	(in.) = 1	foot (ft.)
3 feet	(ft.) = 1	yard (yd.)
5280 feet	(ft.) = 1	mile (mi.)
6080 feet	(ft.) = 1	nautical (mi.)

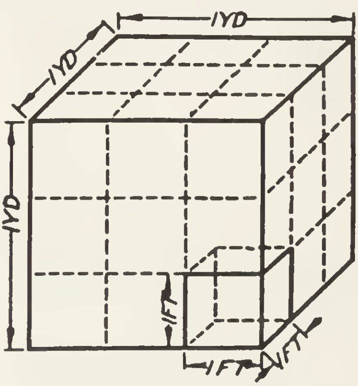
Two dimensional space (area) is also measured in feet and inch units; that is, a square inch or a square foot. 1 square inch is a square area with a 1 inch measurement on each side, Figure 1-1.



1-1. The relation of standard areas.

144 square inches	(sq. in.) = 1 square foot (sq. ft.)
9 square feet	(sq. ft.) = 1 square yard (sq. yd.)

Three dimensional space (volume) is also measured in English units. All substances must be of three dimensions. These measurements are the cubic inch, the cubic foot, and the cubic yard, Figure 1-2. 1 cubic inch (cu. in.) is a cube, 1 inch (in.) on each dimension.



1-2. The relation of standard volumes.

1728 cubic inches	(cu. in.) = 1 cubic foot (cu. ft.)
27 cubic feet	(cu. ft.) = 1 cubic yard (cu. yd.)

1-9. PROBLEMS

1. How many square inches are equal to 4 square feet? Ans. 576
2. How many square feet are equal to 1440 square inches? Ans. 10
3. How many square yards are equal to 1296 square inches? Ans. 1
4. How many cubic inches are equal to 10 cubic feet? Ans. 17280
5. How many cubic feet are equal to 6 cubic yards? Ans. 162

1-10. MASS AND WEIGHT

Mass is a property of all matter, for everything has mass. Gas has mass, water has mass, and metals have mass. The mass is indication of the number of molecules present in a unit quantity of a substance. The weight of a substance is due to the earth's attraction on the substance (gravity). The only condition in which a substance has no weight is when it is falling in a vacuum under the influence of gravity. At all other times it has weight. Therefore, weight divided by acceleration due to gravity is mass. Ordinarily gravity pull on an object will give the object a falling acceleration of 32.2 ft./sec/sec.

Therefore:

$$\text{mass} = \frac{\text{Weight}}{32.2 \text{ ft. per sec. per sec.}} = \text{slugs}$$

The unit of mass is the slug.

It is important to know this slug value because all mass obeys the following rule:

Force = mass x acceleration.

The English units for weight are the ounce, the pound, and the ton.

16 ounces	(oz.) =	1 pound	(lb.)
2000 pounds	(lb.) =	1 ton	(ton)

Example: What is the mass of a 10 lb. substance:

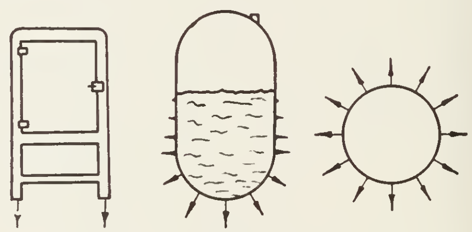
Mass is $\frac{W}{g} = \frac{10}{32.2} = .3106$ slugs

W = Weight of substance

g = 32.2 feet per second per second

1-11. SOLIDS

Substances exist in three physical forms: The solid, the liquid, and the gaseous. Water, for example, may exist in any one of the above physical forms. If it is ice, it is a solid; if it is water, it is a liquid; while as steam, it is a gas. Three different methods are used to express physical properties of substances or materials corresponding to the three states of matter.



1-3. The various ways materials exert pressure. The arrows represent the direction of and the relative amount of the pressures.

A solid is any physical substance which retains a certain shape. It is made of untold billions of molecules, all exactly the same, that stay in the same place relative to each other, and vibrate back and forth. The lower the temperature, the slower the molecules vibrate, and the higher the temperature, the faster the molecules vibrate. These molecules are strongly attached to each other and considerable force is necessary to move them.

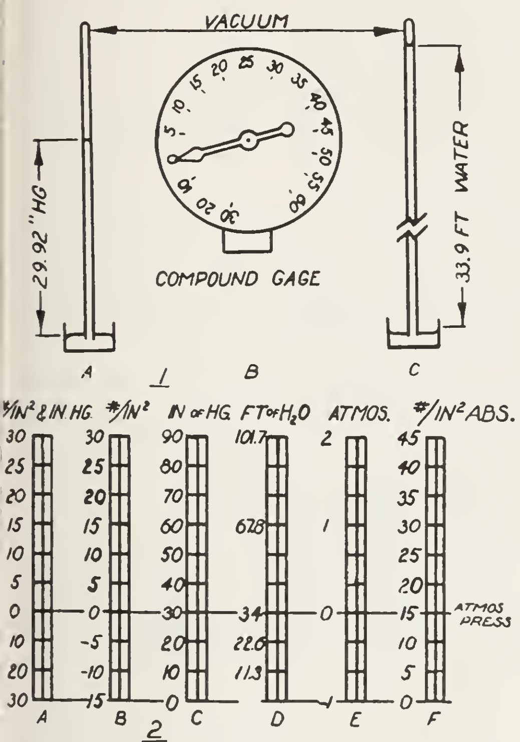
1-12. LIQUIDS

A liquid is any physical substance which will assume the shape of its

container but which has the molecules strongly attached to each other. One could imagine the molecules swimming amongst its fellow molecules but never leaving them. As the temperature rises, the molecules will swim faster and vice versa. Fig. 1-3.

1-13. GASES

A gas is any physical substance which must be contained in sealed container or it will soon dissipate. These molecules have little attraction



1-4. The standard pressure scales and the different ways of registering atmospheric pressure.
1. A simple mercury barometer is shown at (A). The compound gauge (B) is calibrated in inches of mercury for pressures below atmospheric, and in pounds per square inch gauge for pressures above atmospheric. The water column (C) illustrates the water equivalent of the mercury barometer.
2. This illustrates pressures of from 0 pounds per square inch to 30 pounds per square inch gauge expressed in common units. It may be noticed that all values, reading horizontally, are equal. The apparent difference in readings is due to the scale used.

for each other and travel in a straight line (fly) and will ricochet or rebound from any other molecules they contact. They have no attraction for each other or any other substance.

Any particular substance can be made to exist in any of these three forms. Any molecule can be made to vibrate, or swim or fly depending on two things: temperature and pressure. Before one can understand this change of state, he must study temperature and pressure.

Comparative weights of solids and liquids may be expressed by either density or specific gravity. Density is defined as the weight per unit volume. Specific gravity is defined as the ratio of the weight of a certain volume of a substance to the weight of an equal volume of water.

Comparative densities of gases are expressed by specific volumes. Specific volume is the volume of one pound of a gas at standard conditions. Standard conditions are considered to be 68 F. and 29.92 inches of mercury column pressure. See Figures 1-4 & 1-5.

1-14. SYMBOLS

F = Degrees Fahrenheit
C = Degrees Centigrade
F_A = Degrees Fahrenheit Absolute
C_A = Degrees Centrigrade Absolute

p = pounds = lbs.
psi = pounds per square inch = lbs., per sq. in.
i = inches = in.
f = foot or feet = ft.
si = square inch = sq. in.
sf = square feet or foot = sq. ft.
pcf = pounds per cubic foot = lbs. per cu. ft.

Example: What is the specific volume of air if 10 cubic feet of it weighs .75 pounds?

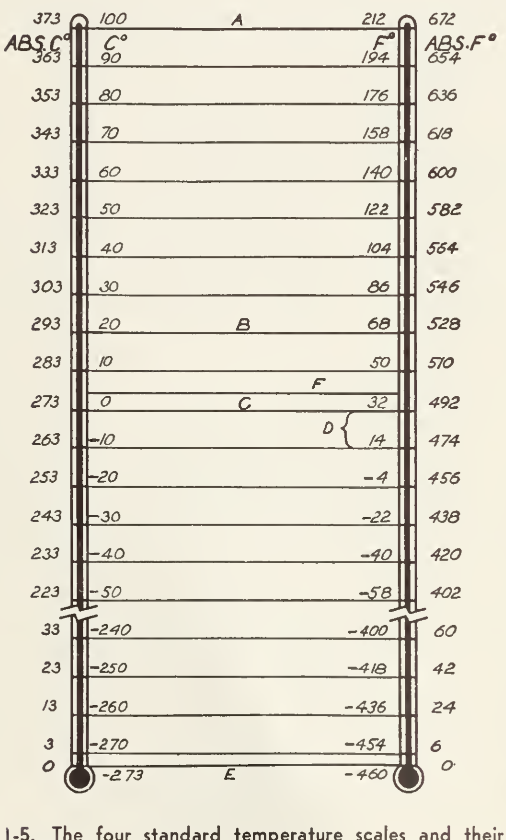
$$\text{Specific Volume} = \frac{\text{Volume in cu. ft.}}{\text{Weight in lbs.}} = \frac{10}{.75} = 13.3 \text{ cfp}$$

Example: If 1 cubic foot of iron weighs 490 pounds what is its specific gravity? Density of water - 62.4 pcf. Specific gravity of iron =

$$\frac{490 \text{ pounds per cubic foot}}{62.4 \text{ pounds per cubic foot}} = 62.4$$

Examples: What is the density of a liquid if 3000 cubic inches of it weighs 108.5 pounds?

$$\frac{108.5 \text{ pounds} \times 1728 \text{ cubic inches per cubic foot}}{3000 \text{ cubic inches}} = \frac{108.5 \times 1728}{3000}$$



1-5. The four standard temperature scales and their relationship. A. Boiling temperature of water at atmospheric pressure; B. Average room temperature; C. Freezing temperature of water at atmospheric pressure; D. Cooling unit temperature range; E. Absolute zero temperature; F. Average refrigerator box temperature.

Density of the liquid = 62.4 pounds per cubic foot

1-15. PRESSURE

As the operation of a refrigerator depends mainly on pressure differences in the system, a basic understanding of pressure and of the laws of pressures is very important.

Pressure is defined as the weight per unit area, and it is expressed in pounds per square inch and pounds per square foot. The normal pressure of the air on the body averages about 14.7 pounds per square inch, or 2117 pounds per square foot. Note: There are 144 square inches in 1 square foot; therefore to get the pressure per square foot, 14.7 must be multiplied by 144.

Substances always exert a pressure upon the surfaces supporting them. That is, an ice-box (a solid) exerts a pressure on its legs because if they were removed the box would move; a liquid always exerts a pressure on the sides and bottom of its container, such as a bottle; and a gas always exerts a pressure on all the surfaces of its container, such as a balloon. See Figure 1-3.

If a solid weight of 1 pound were made with its bottom surface area 1 inch square, it would exert a pressure of 1 pound per square inch upon a flat surface.

A liquid in a container maintains an increasing pressure on the sides as the liquid depth increases and a constant pressure on the bottom of the container. Gases, however, do not always exert a constant pressure on the container because the pressure is determined by the temperature and the quantity in the container.

1-16. PRESSURES, GAGE AND ABSOLUTE

Pressures are expressed in pounds per unit of area or in inches of static pressure of liquids. The most popular pressure indicating instruments register in pounds per square inch ABOVE the atmospheric pressure. The pressure of zero pounds per square inch gauge is equal to the atmospheric pressure (approximately 14.7 pounds per square inch; 15 pounds per square inch is usually used for computation purposes). Pressures below atmospheric pressure are termed vacuums and a perfect vacuum may be described as - 14.7 pounds per square inch gauge or 0 pounds per square inch absolute. Therefore, the absolute pressure scale has its zero at a pressure which cannot be further reduced. Pressure is also indicated in inches of mercury or water column and may be either above atmospheric pressure or absolute pressure depending on the construction of the gauge. Mercury is usually used for measuring pressures below atmospheric pressure and water for SMALL PRESSURES above. (GAS LINES, ETC.)

The barometer, Figure 1-4, is an example of a mercury gauge. With a vacuum in one end of the tube, it is found that the atmospheric pressure will support a mercury column 29.92 in. in height at sea level under standard conditions.

1-17. BOYLE'S LAW

Boyle's Law expresses a very interesting relation between the pressure and volume of a gas. It is stated as follows:

"The volume of a gas varies inversely as the pressure provided the temperature remains constant."

This means if a certain quantity of gas has its pressure doubled, the volume becomes one-half that of the original. Or, if the volume becomes doubled, the gas has its pressure reduced by one-half. If a perfect gas is considered, Boyle's Law may be expressed as a formula:

Pressure x Volume = A constant number.

This being true, one can say that when either the pressure or the volume is changed, the corresponding pressure or volume is changed in the opposite direction. Therefore, Old Pressure x Old Volume = the New Pressure x the New Volume. THIS FORMULA WILL HOLD TRUE ONLY IF THE PRESSURES ARE EXPRESSED AS ABSOLUTE PRESSURES. Expressed in letter form:

$$P_o \times V_o = P_n \times V_n$$

Example:

What is the new volume, if 5 cubic feet of gas at 20 pounds per square inch gauge are compressed to 60 pounds per square inch providing the temperature remained constant? Consider atmospheric pressure = 15 pounds per square inch.

$$P_o \times V_o = P_n \times V_n$$

P_o = 20 pounds per sq. in. gauge = (20 + 15) = 35 pounds per sq. in. abs.

V_n = 60 pounds per sq. in. gauge = (60 + 15) = 75 pounds per sq. in. abs.

$$35 \times 5 = 75 \times V_n$$

$$\frac{35 \times 5}{75} = V_n$$

$$\frac{35}{15} = V_n$$

$$\frac{7}{3} = V_n$$

2.33 cubic feet = V_n = New Volume

1-18. DALTON'S LAW

Dalton's Law of partial pressures is the foundation of the principle of operation of one of the absorption type refrigerators. The law may be stated as follows:

"The total pressure of a mixture of gases is the sum of the partial

pressures of each of the gases in the mixture.''
The total pressure of the air is the sum of the oxygen, the nitrogen, the carbon dioxide, and the water vapor pressure.

The law further explains that each gas behaves as if it occupies the space ALONE. This explains why water will evaporate from a floor after a scrubbing. The water vapor pressure is so low in the air that the water will turn to water vapor (very slowly of course) at temperatures of 70 F. down to freezing.

1-19. FORCE

Force is accumulated pressure. If a piston of 10 sq. in. area has a pressure on it of 25 lbs. per sq. in., the force on the piston is: 10 x 25 = 250 lbs.

1-20. WORK AND ENERGY

A complete study of energy relations is also necessary to a complete understanding of refrigeration. ENERGY is described as ''THE CAPACITY TO DO WORK,'' where WORK is defined as ''FORCE MULTIPLIED BY DISTANCE THROUGH WHICH IT TRAVELS.'' The unit of work is called the foot-pound. One foot-pound is the amount of work done in lifting a one pound weight a vertical distance of one foot. Work is sometimes expressed in inch-pounds. In this case, the distance through which the force acts is measured in inches.

Example: Calculate the work done in foot-pounds in lifting a weight of 2000 pounds a vertical distance of 10 feet.

Work = Force x Distance
= 2000 x 10 = 20,000 foot-pounds
or expressed in inch units
2000 x 10 x 12 = 240,000 inch-pounds

Energy is the ability to do work. The electric motor supplies the energy to drive the refrigerator compressor.

1-21. POWER

POWER IS DEFINED AS THE TIME RATE OF DOING WORK. The common unit of mechanical power is the horsepower and is the equivalent of 33,000 foot-pounds of work per minute. If in the above problem the 200-pound weight is lifted 10 feet in 2 minutes, the power required would be:

$$\text{Horsepower} = \frac{\text{weight x distance}}{\text{time x } 33{,}000} \quad \text{or}$$

$$\text{Horsepower required} = \frac{200 \times 10}{2 \times 33{,}000} =$$

.3 Horsepower

1-22. TEMPERATURE

Temperature is defined as the heat intensity or heat level of a substance. Temperature alone does not give the amount of heat in a substance, but it is an indication of the degree of warmth, or how hot the body is.

The molecular theory of heat states that temperature is an indication of the speed of motion of the molecule. It is important not to use the words heat and temperature carelessly. Temperature measures the speed of motion of one molecule, while heat is the speed of motion of the molecule PLUS the number of molecules (weight) so effected. Example: A small copper dish heated to 1340 F. does not contain as much heat as 5 pounds of copper heated to 300 F. but it is warmer. That is, its heat level is higher or its intensity of heat is greater, but it does not contain so much heat.

1-23. TEMPERATURE SCALES

The methods and scales used to measure temperatures have been arbitrarily chosen by scientists, and the following standards have been established. The common British and American scales are the Fahrenheit scale

and the Fahrenheit absolute scale, while the metric system embodies the Centigrade and Centigrade absolute scales. The Fahrenheit scale is the one most used in the refrigeration industry.

The Fahrenheit scale is so fixed that it divides the temperature difference from the melting temperature of ice to the boiling temperature of water into 180 equal divisions and sets the melting of ice at 32 divisions above the zero on the scale. Therefore, ice melts at 32 F. and water boils at 212 F. (180 F.+32F.) assuming standard atmospheric pressures.

The Centigrade scale has coarser divisions than the Fahrenheit scale and the zero (0) of this scale is set at the melting temperature of ice. The boiling point of water is fixed 100 divisions above that point or at 100 C. assuming standard atmospheric pressure.

1-24. ABSOLUTE TEMPERATURE SCALES

The Fahrenheit absolute (F_A) scale is a scale using the same divisions as the Fahrenheit scale but setting the zero of the scale at the temperature where molecular action of all substances ceases; i. e., where no more heat exists in the body and the temperature cannot be lowered any farther. This temperature corresponds to -460 F., therefore water boils at 672 F_A assuming (212 + 460 = 672) standard atmospheric pressure. Because the Centigrade degree is coarser absolute zero is 273 degrees below the standard zero setting, therefore, water freezes at 273 C_A and boils at 373 C_A.

The student may wonder why the melting temperature of ice and the boiling temperature of water were taken as standards. This is because water has a very constant freezing and boiling point temperature, Figure 1-5, and water is a very common substance.

1-25. TEMPERATURE CONVERSION

It is sometimes necessary to convert a temperature registered in Fahrenheit degrees to Centigrade degrees, or conversely. For this purpose formulas have been developed, based upon the fact that Fahrenheit zero is located at 32 below the Centigrade zero and the distance between the freezing-point of water and the boiling-point of water is 180 on the Fahrenheit scale and 100 on the Centigrade scale. To convert Centigrade degrees into Fahrenheit degrees:

$F = 180/100 = 9/5\ C + 32$

To convert Fahrenheit degrees into Centrigrade degrees:

$C = 100/180 = 5/9\ (F - 32)$

To convert Fahrenheit degrees to Fahrenheit absolute:

$F_A = F + 460$

To convert Centigrade degrees into Centigrade absolute:

$C_A = C + 273$

Example:

Convert 50 F. into Centigrade.

$C. = 5/9\ (F - 32)$

$C. = 5/9\ (50 - 32)$

$C. = 5/9 \times 18$

$C. = \frac{5 \times 18}{9} = \frac{90}{9} = 10\ C$

Convert 75 C. into Fahrenheit.

$F. = 9/5\ C. + 32$

$F. = 9/5 \times 75 + 32$

$F. = \frac{9 \times 75}{5} + 32$

$F. = 9 \times 15 + 32$

$F. = 135 + 32$

$F. = 167$

Convert -- 5 F. into C.

$C. = 5/9\ (F. - 32)$

$C. = 5/9\ (-5 - 32)$

$C. = 5/9\ (-37)$

$C. = \frac{5 \times -37}{9} = \frac{-185}{9} = -20\ 5/9 =$

$-20\ 5/9$ C.

1-26. CHARLES' LAW

Gases behave consistently with temperature changes. This is stated in Charles' Law. "At a constant pressure the volume of a gas varies directly as the absolute temperature; and at a constant volume, the pressure varies directly as the absolute temperature." Absolute pressures must always be used in the equations. In the equation form:

At constant volume

The Old Pressure x the New Absolute Temperature = The New Pressure x the Old Absolute Temperature

$Po \times Tn = Pn \times T$

T = Absolute Temperature

At constant pressure

The Old Volume x the New Absolute Temperature = The New Volume x the Old Absolute Temperature

$Vo \times Tn = Vn \times To$

Example: What is the pressure of a quantity of confined gas when raised to 60 F. if its original pressure was 10 pounds per square inch abs. and temperature 40 F., Constant Volume?

Answer:

$10 \times (60 + 460) = X \times (40 + 460)$

$$\frac{10 \text{ pounds}}{X} = \frac{500}{520}$$

$500 X = 5200$

$X = 10.4$ pounds per square inch abs.

Example: A 5 cubic feet volume of gas at 37 F is raised to 90 F at constant pressure. What is the new volume?

Answer:

$5 \times (90 + 460) = X \times (460 + 37)$

$$\frac{5}{X} = \frac{497}{550}$$

$$X = \frac{5 \times 550}{497} = 5.54 \text{ cubic feet}$$

1-27. GAS LAW

Boyle's Law and Charles' Law may be combined to solve true gas problems and the formula is as follows:

$$\frac{Po \times Vo}{To} = \frac{Pn \times Vn}{Tn}$$

Po, Vo, and To represent original conditions.

Pn, Vn, and Tn represent new conditions.

Absolute values for temperatures and pressure must be used in this equation.

A more concrete equation is: PV=WRT

Where P = Pressure in Pounds Per Square Foot abs.

V = Volume in Cubic Feet

R = Gas Constant

W = Weight of the Gas in Pounds

T = Absolute Temperature F.

This equation is useful for many pressure-volume problems and its use is easily followed.

	Specific Heat CP	CV	R
Air............	.24	.17	53.34
Ammonia........	.51	.35	123.24
Sulphur dioxide	.154	.123	24.14
Carbon dioxide.	.22	.17	38.82
Ether..........	.48	.45	23.11
Oxygen.........	.22	.16	48.55
Alcohol........	.45	.40	41.55
Water vapor....	.480	.37	83.23

1-6. A table of gas values.

R = Gas constant and it must be known for the gas under consideration. Figure 1-6 lists the value of R for several common gases.

1-28. BRITISH THERMAL UNIT

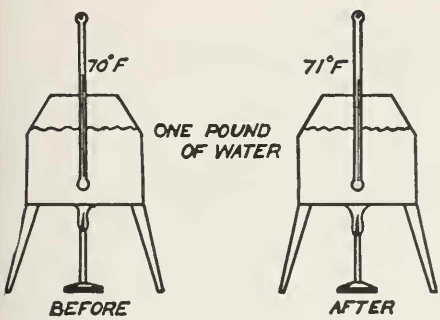
British thermal units (Btu): Temperature is measured in degrees by the use of a thermometer. Heat is measured in Btu's. A Btu is defined as the amount of heat required to raise the temperature of 1 pound of water, 1 degree Fahrenheit, Figure 1-7.

1-29. ENERGY CONVERSION UNITS

In refrigeration work we deal with three common forms, mechanical

electrical, and heat energy.

The study of refrigeration deals mainly with heat energy, but it must be understood that the heat energy is usually produced by utilizing a combination of electrical and mechanical energy. There is a relation that exists between these three forms of energy. In an electric refrigerating unit, electrical energy flows into an electric



1-7. A simple experiment to demonstrate the addition of one British Thermal unit of heat. One pound of water is heated 1° Fahrenheit.

motor and this electric energy is turned into mechanical energy. This mechanical energy is used to turn a compressor, and the compressor in turn changes the mechanical energy into heat energy as it compresses the gas to a high temperature (adds heat). This relationship may be expressed as follows:

778 foot-pounds = 1 British Thermal Unit (Btu)

1 H. P. = 2545.6 Btu/hr.

1 H. P. = 746 Watts

1 Btu/hr. = .000393 H.P.

1 Btu/hr. = .293 Watts

1 watt = .00134 H.P.

1 watt = 3.41 Btu/hr.

1-30. SENSIBLE HEAT

If a substance is heated (heat added) and the temperature rises as the heat is added, the increase in heat is called sensible heat. Likewise heat may be removed from a substance (heat subtracted) and if the temperature falls the heat removed is again sensible heat. Therefore, we call that heat which causes a change in temperature in a substance sensible heat.

1-31. SPECIFIC HEAT

The sensible heat required to cause a temperature change in substances varies with the kind of substance and the amount of the substance. The specific heat of water is 1.0. Different substances require different amounts of heat per unit quantity to effect these changes of temperature. This property is called the specific heat of the substance and is the amount of heat required to raise 1 pound of the substance 1 F. This value is good for computations which involve no changes of state because if this should occur, the specific heat of the substance changes also. To determine the amount of heat necessary to cause a change of temperature in a substance multiply the weight of the substance by the specific heat and by the temperature change provided there is no change of state, Figure 1-8.

Material	Specific Heat (B.T.U./lb.)
Wood	.327
Water	1.
Ice	.504
Iron	.129
Mercury	.0333
Alcohol	.615
Copper	.095
Sulphur	.177
Glass	.187
Graphite	.200
Brick	.200
Glycerine	.576
Liquid ammonia at 40 F.	1.1
Carbon dioxide at 40 F.	.6
Methyl chloride...40 F.	.38
Sulphur dioxide at 40 F.	.35

1-8. Some specific heat values.

Specific heat problems are easily solved by the use of the following formula:

Heat = British Thermal Units = sp. ht. x wt. x temp. change in degrees F.

Btu = sp. ht. x wt. x temp. change

Btu = sp. ht. x wt. x $(t_1 - t_2)$

Btu = British Thermal units

sp. ht. = Specific heat

t_1 = higher temperature

t_2 = lower temperature

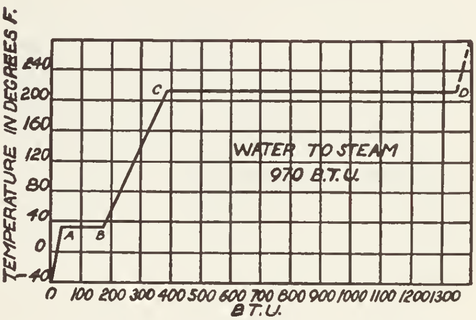
Example: How much heat is needed to raise the temperature of 100 pounds of iron from 70 F. to 270 F.?

Btu = .129 x 100 x (270 - 70)

Btu = .129 x 100 x 200

Btu = .129 x 20,000

Btu = 2,580.1



1-9. A graph of the three states of water and the heat required to effect the change at atmospheric pressure for one pound of water. From −40 F. to A, 36 B.T.U. were added to the one pound of ice, raising its temperature to 32° F.
From A to B, 144 B.T.U. were added to melt the ice. Note that the temperature did not change.
From B to C, 180 B.T.U. were added and the temperature of the water was changed to 212° F.
From C to D, 970 B.T.U. were required to change the water to steam at 212° F.

1-32. LATENT HEAT

A physical phenomenon of all pure substances is their ability to change their state, such as solid to liquid and liquid to gaseous. These changes of state occur at the same temperature and pressure combinations for any one substance. It takes addition of heat or the removal of heat to produce these phenomena. We call heat which brings about a CHANGE OF STATE, LATENT (hidden) HEAT.

There are two latent heats for each substance, solid to liquid heat (melting and freezing) and liquid to gaseous (vaporizing and condensing), Figure 1-9. These are called the latent heat of melting and the latent heat of vaporization respectively, if the substance is being heated. These are called latent heat of fusion and the latent heat of condensation if the substance is being cooled (heat energy subtracted).

The explanation for the change of state is that as the molecule moves under a certain pressure it will increase to a certain speed and then if heat is added the molecule undergoes a peculiar change. This change is a change that takes place within the molecule. It is believed that there is a shift of the atoms within the molecule. It is estimated that one or more of the atoms change their position from the outer face of the molecule to the inside or just the reverse. There are other theories, all of them based on molecular motion and magnetic attraction. The heat energy needed to make this change is tremendous. It takes as much heat to change one pound of ice to one pound of water as it does to raise that same one pound from 32 F. to 176 F.

The difference between sensible heat and latent heat should be kept very clearly in mind because all of the following explanations of the refrigeration cycle are based upon these two heats, SENSIBLE and LATENT.

1-33. APPLICATION OF LATENT HEAT

In refrigeration work, the physics of latent heat is of special importance because it is this heat which gives us our cold or freezing temperatures. When ice melts its temperature re-

mains constant; nevertheless it absorbs a considerable amount of heat changing from ice to water. When a substance passes from a liquid to a gas as in a mechanical refrigerator, its heat absorption is very high, and advantage is taken of this fact in the operation of the refrigerator.

The temperature at which a substance changes its state depends on the pressure. The higher the pressure the higher temperature needed to make the change of state take place. Also if the pressure can be lowered, the temperature at which the change of state will take place will also be lowered. For example water will turn to steam at 212 F. at 14.7 psia, at 300 F. at 67 psia, 400 F. at 247 psia, 100 F. at .95 psia, 70 F. at .36 psia, 40 F. at .12 psia.

If a low pressure is produced over a liquid it will boil at a lower temperature and if a gas resulting from this boiling is compressed it will condense to a liquid at a higher temperature.

Every substance has a different latent heat value to bring about a change of state for both liquid-solid and liquid-gaseous states. Latent heats for water and the more common refrigerants are shown in Figure 1-10.

Latent Heat of Water and Common Refrigerants in B.T.U./lb.

Material	Freezing or Melting	Condensing or Vaporizing
Water	144	970.4 (at 212 F.)
Ammonia	...	565.0 (at 5 F.)
Sulphur dioxide	...	169.38 (at 5 F.)
Methyl chloride	...	178.5 (at 5 F.)
Freon (F-12)	...	69.5 (at 5 F.)
Freon 22	...	93.6 (at 5 F.)
Carrene (methylene chloride) ...	...	162.0 (at 5 F.)

1-10. Some latent heat values.

1-34. REVIEW PROBLEMS ON HEAT

1. Convert 78 F. to C. Ans. 25.6 C.
2. Convert 20 C. to F. 68 F.
3. Convert 5 F. to C. 15 C.
4. Convert 432 F. to C. 222C.
5. Convert 14 F_A to C_A. 10C_A.
6. What is the equivalent of 20 kilowatts in
   (a.) British Thermal units? 68.297.59 Btu/hr
   (b.) Food-pounds? 884,730 foot p/min
7. What is the new volume of 50 cubic feet of gas if the pressure changes from 35 pounds per square inch gauge to 85 pounds per square inch gauge? 24 cu. ft.
8. How many British Thermal units must be extracted to cool 10 pounds of iron from 70 F. to 10 F.? 77.4 Btu
9. How many British Thermal units must be removed from a cooling unit to cool it from 85F. to 15 F., if it contains 10 pounds of copper and 20 pounds of glycerine? 872.9 Btu
10. Calculate the number of British Thermal units required to convert 1 pound of ice at 0 F. to steam at 212 F. Ans. 1310.52 Btu

1-35. REFRIGERATION EFFECT OF ICE

Ice has played an important part in the refrigeration industry. A few important facts concerning it follow:

As stated before, ice changes to water at 32 F. at atmospheric pressure, and the water changes to steam at 212 F.

The heat absorption ability of ice when changing from a temperature below 32 F. to 32 F. is .504 British Thermal units per pound per degree change in temperature. Changing ice to water at 32 F. the heat absorption is 144 British Thermal units for 1 pound of ice changing to 1 pound of water. That is,

The specific heat of ice = .504 Btu per pound

The latent heat of fusion of ice = 144 Btu per pound

The specific heat of water = 1 Btu per pound

The latent heat of vaporization of water = 970.4 Btu per pound

Example: How many Btu will 25 pounds of ice at 5 F. absorb in changing to liquid at 40 F.?

From ice at 5 F. to ice at 32 F.

.504 x 25 x (32 - 5)

.504 x 25 x 27 = 340.2 British Thermal units

From ice to water at 32 F.

144 x 25 = 3600 British Thermal units

From water at 32 F. to water at 40 F.

1 x 25 x (40 - 32)

1 x 25 x 8 = 200 British Thermal units

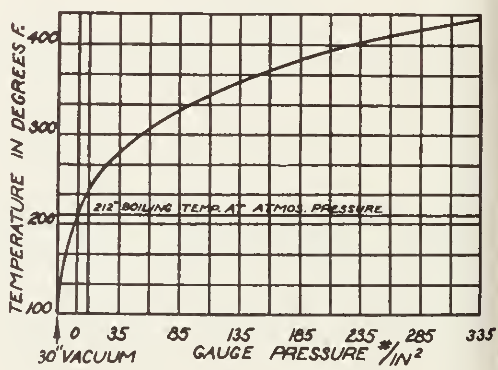
340.2
3600
200
Total 4140.2 British Thermal units

1-36. THE "TON" OF REFRIGERATION EFFECT

This refrigeration unit is the refrigeration effect obtained from melting 1 ton (2000 lbs) of ice over a period of 24 hrs. This engineering standard for refrigeration effect applies to all refrigerating machines. That is, all the refrigeration mechanisms are compared to the standard 288,000 British Thermal units per twenty-four hours. (144 x 2000 = 288,000)

1-37. ICE AND SALT MIXTURES

Refrigerating by ice will not give continuous refrigeration temperatures below 40 F; therefore to obtain lower temperatures required in some instances, ice and salt mixtures are used. These mixtures, ice and salt (NaCl) and ice and calcium chloride (caCl) lower



1-11. The vapor pressure curve for water. The pressures and temperatures required to permit a change from water to steam or vice versa.

the melting temperature of ice. That is, an ice and salt mixture may be made which will melt at 0 F. The reason for lowering the temperature below normal with an ice and salt mixture is because the salt causes the ice to melt faster and this forced absorption of heat causes the lower temperature which results from the mixture. See the technical characteristics chapter for table of ice and salt mixtures, and corresponding temperatures.

1-38. EFFECT OF PRESSURE ON EVAPORATING TEMPERATURES

The boiling temperature for any liquid depends upon the pressure under which the liquid is placed. Water normally boils at 212 F., but if the pressure on the surface of the water is increased to 100 pounds per square inch gauge, the boiling-point will be raised to 338 F. If instead of increasing the pressure it is decreased to an absolute pressure of 3 pounds per square inch, the water will boil at 142 F. Figure 1-11.

It is the effect of reduced pressure on the boiling temperature of certain liquids that makes the operation of the domestic refrigerator possible. As an illustration of this, sulphur dioxide boils at 14 F. under atmospheric pressure while at 8 inches of vacuum the boiling temperature is 5 F. See Figure 8-17 for a graph of the temperature characteristics of sulphur dioxide.

1-39. HEAT TRANSFER

The movement of heat may be by any one of three methods, or by a combination of any two or of all three of these methods. These heat transfer methods are named conduction, convection, and radiation.

1-40. CONDUCTION

Conduction is the flow of heat from one part of a substance to another part of the same substance, or from one substance to another substance in direct contact with it. A piece of iron with one end placed in a fire will soon become warm from end to end. This is an example of the transfer of heat by conduction. The heat travels through the iron using the iron as the conduction medium. The substances which have a very small conduction value are called insulators.

1-41. CONVECTION

Convection is the conveying of heat from one point to another by the movement of some easily circulated medium such as air. A common example of this is the movement of heat-laden air from a furnace into the rooms of a house where it releases its heat and then returns through the cold air duct to receive another supply of heat from the furnace.

1-42. RADIATION

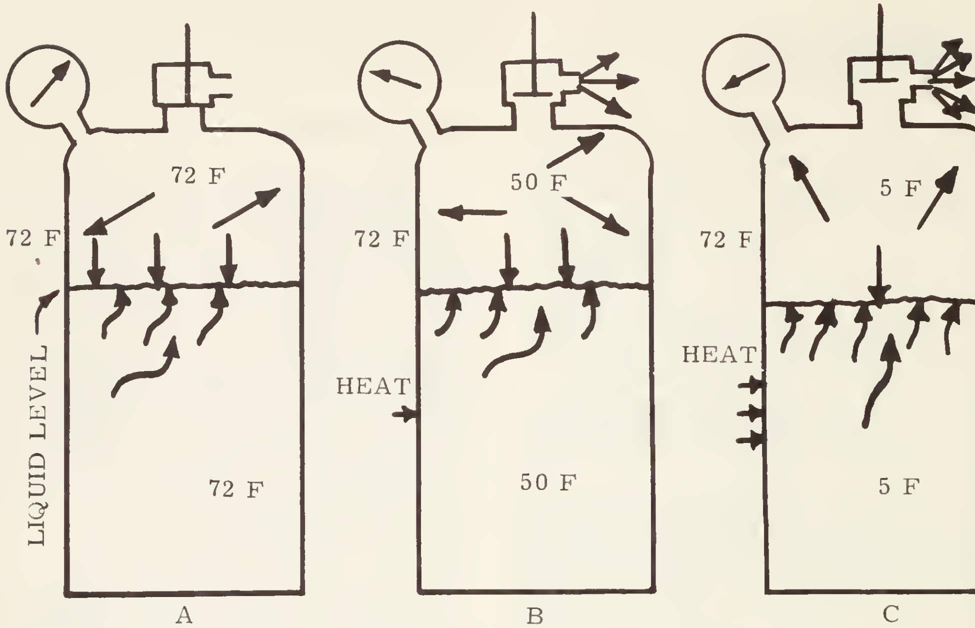
Radiation is the transfer of heat by heat rays. Examples of this are the heat from the sun and the heat felt near a flame. It should be understood that heat rays do not heat the air through which they pass. They heat only the surfaces which they strike.

1-43. CONTROL OF HEAT FLOW

The flow of heat by each of these methods can be controlled. That is, the transfer of heat by each of these methods can be aided or impeded according to the particular need. Conduction may be aided by providing large conducting surfaces and good conducting materials. Cork, wood, mineral wool, and many other similar materials are poor conductors of heat. Poor conductors of heat are often referred to as heat insulators.

Convection may be aided by speeding the flow of the conveying medium; for example, forced-air circulation heating systems. Conversely, it can be impeded by retarding the flow of circulation.

Radiation, or rather the transfer of heat by radiation, may be aided by making the radiating surfaces of a material or of a color known to be a



1-12. The cooling effect of different pressures operating on the surface of a liquid.

good radiator of heat and, by making the receiving surfaces of a material or color known to be a good absorber (or poor reflector) of radiated heat. Conversely, it may be impeded by reversing this application. Dark materials or colors absorb and radiate readily. Light-colored or shiny materials have the opposite properties.

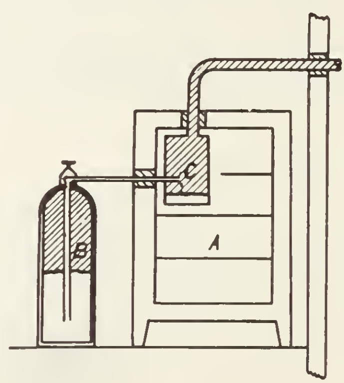
1-44. THE ELEMENTARY REFRIGERATOR

A detailed study of the behavior of a liquid in a container is necessary to understand the operation of a refrigerating unit.

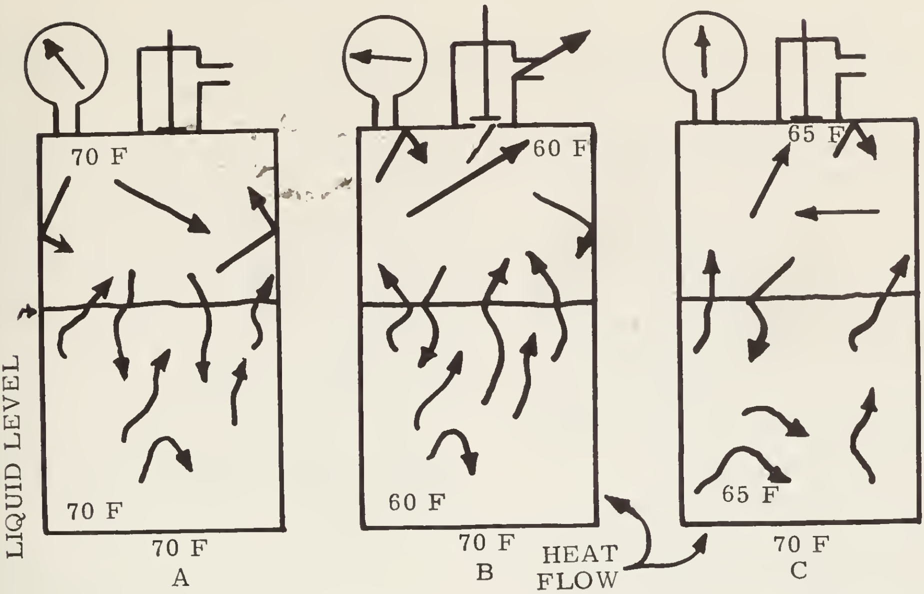
In Figure 1-12, part A shows a refrigerant in a container with the valve closed.

All conditions are balanced. The pressure, the temperature (inside and out), and the number of molecules leaving the gaseous state diving into the liquid and the liquid molecules flying out of the liquid into the gaseous state.

In part B, the valve has been opened and some of the gas molecules escape. The results are two fold. The number of gas molecules entering the liquid are now decreased and because the number leaving the liquid is the same as before, the molecular speed of the liquid molecules slows up as they find it easier to



1-13. An elementary refrigerator using ammonia (not practicable). A. The refrigerator box; B. The ammonia tank in which the ammonia is stored under a high pressure; C. The cooling unit where the ammonia is changed from a liquid to a gas at atmospheric pressure and absorbs a considerable amount of heat.



1-14. The theoretical explanation of vapor pressure in a sealed container. A. Valve closed; B. Valve open; C. Valve closed.

change to a gas. Slower movement means a lower temperature and the liquid temperature lowers below 70 F. The temperature decrease causes heat to flow from the container and the surroundings to the liquid.

As long as the valve is open and gas molecules can escape the temperature will be lower because more liquid molecules are becoming gas molecules than gas molecules are returning into the liquid, Part C. This gas bombardment is called vapor pressure. If this vapor pressure can be reduced the temperature of the liquid can be reduced.

If the gas molecules can be removed fast enough by any means such as a compressor, a chemical to absorb the molecules, etc., a vapor pressure low enough is produced to create refrigerant boiling temperatures that are at the refrigerating level.

The operation of the electric refrigerator is based on the heat absorption property of a fluid passing from the liquid to the gaseous state. That is, if one were to put a container of fluid that had a low boiling temperature into an ice-box and vent the gas to the outside, we would have a heat absorber in the box, Figure 1-13. The liquid can boil only at its evaporation temperature, say 20 F., and this liquid will be at this temperature until it has completely evaporated. If one tried to raise its temperature by adding heat, the only result would be a more rapid evaporation of the liquid into a gas, provided the pressure remained constant. Being at this low temperature there is, of course, a transfer of heat to it from the surrounding objects. This heat helps the evaporating and the heat carried away in the vapor passing off. Thus, the fluid changing its state to gas gets the energy (or heat) for doing this from the objects surrounding it and that heat is removed with the vapor to the outside of the box.

Figure 1-14 illustrates maintaining a balance between liquid and vapor with changing pressure. (A) shows a state of equilibrium between the liquid and the vapor. In (B) the valve has been opened and the pressure partially re-

leased. Vapor escapes and attempting to maintain the vapor pressure more liquid vaporizes and the temperature drops. In (C) the valve is closed and a state of balance will not be reached until the temperature returns to normal.

This type of refrigerator works very nicely, but it is a very expensive method because the refrigerant fluid is lost. However, in the mechanical refrigerator this escaping vapor is captured, compressed, and cooled to a liquid state again so that it can be used over and over, Figure 1-15.

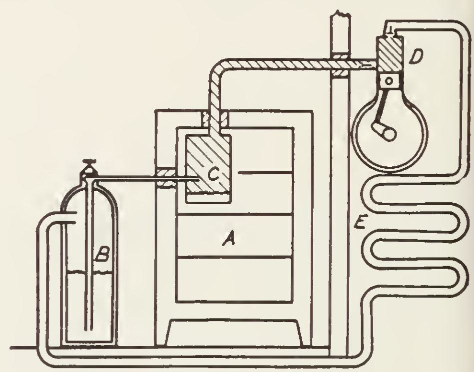
The above gas needs to be compressed again before it will return to the liquid form. In order to recondense the vaporized refrigerant, the vapor must be compressed to a pressure, corresponding to a boiling-point that is higher than the maximum room temperature in which the refrigerator is to operate in order that the latent heat of vaporization may be radiated to the room. The temperature at which a refrigerator cooling unit is kept depends upon the pressure at which the refrigerant is evaporated, while the amount of heat removed depends only upon the amount of refrigerant changed into a gas.

1-45. DRY ICE

Solid carbon dioxide is often used for refrigeration. It is a white crystalline substance formed by allowing liquid carbon dioxide to escape into a snow chamber. The heat for vaporizing the liquid is drawn from the interior of the chamber so that a very low temperature, — 109 F. is formed, with the result that quantities of the carbon dioxide solidify. This solid is pressed into various shapes and sizes and sold for refrigeration purposes under such names as dry ice, zero ice, etc. It remains at a temperature of — 109 F. and sublimes, that is, it goes directly from the solid to the vapor state without becoming a liquid. It has some very desirable characteristics in that it does not wet the surfaces that it touches, and the gas given off is a preservative. The very low temperature maintained permits handling frozen goods without an expensive insulated container. It is used a great deal by ice cream vendors and the like.

The latent heat of sublimation is 248 Btu per pound.

The heat absorbed by the vapor in passing from — 109 F. to 32 F. is approximately 27 Btu per pound. This



1-15. An elementary mechanical refrigerator. A. The refrigerator box; B. The storage tank for the liquid ammonia; C. The cooling unit where the ammonia vaporizes and absorbs considerable heat; D. The compressor which takes the vaporized ammonia from the cooling unit and compresses it to a high pressure and releases it to the condenser; E. The condenser where the compressed ammonia is cooled and the latent heat removed allowing it to condense and pass to the storage tank as a liquid.

added to the latent heat of sublimation makes a total heat-absorbing capacity of 275 Btu per pound. This is a greater heat-absorbing value than for water ice. Dry ice is generally more expensive per pound than water ice.

1-46. CRITICAL TEMPERATURE

The critical temperature of a substance is the maximum temperature at

which the substance may be liquefied, regardless of the pressure applied upon it. Refer to the table, Figure 8-1, for the list of critical temperatures for refrigerants. The condensing temperature for all refrigerants must be kept below the critical temperature for the refrigerant used; otherwise the refrigerator would not operate. Carbon dioxide has the critical temperature of 87.8 F. This refrigerant cannot be used in air-cooled condensers because the condensing temperature would be above this temperature.

It is well to keep in mind during the ensuing chapters that the average correct refrigerating temperature for domestic refrigerators is between 35 F. and 45 F. and to make ice, a temperature lower than 32 F. is needed.

1-47. AMBIENT TEMPERATURE

The term ambient temperature is used to denote the temperature of the air surrounding a motor, a control mechanism, or other device. As an example a motor may be guaranteed to deliver its full horse power under operating conditions when the ambient temperature does not exceed 40 C. This means that the temperature of the air surrounding the motor must not exceed 40 C. if the motor is to maintain its operating efficiency.

1-48. REVIEW PROBLEMS AND QUESTIONS

The answers to these problems and questions will be found in Paragraph 1-49, page 721.

1. What is the absolute pressure equivalent in pounds per square inch of 8 inches of mercury vacuum?
2. What is the gas space in the cylinder of a compressor if it has a 2-inch bore and a 3-inch stroke?
3. If 100 cubic inches of a gas at 15 pounds per square inch gauge were compressed to 20 cubic inches, what is the gauge pressure if the temperature remains constant?
4. If 100 cubic inches of gas under constant pressure were changed from 40 F. to 290 F., what is the new volume?
5. How many Btu's will be required to change 5 pounds of ice at 32 F. into water at 82 F.?
6. How many pounds of sulphur dioxide must be evaporated 5 F. to change 50 pounds of water from 72 F. to ice at 5 F. if the container for the water is made of copper and weighs 3 pounds?
7. If 2 cubic feet of gas at 90 F. and under a pressure of 15 pounds per square inch gauge is changed to 4 cubic feet at 40 F., what is the new gauge pressure?
8. What is the pressure difference between 6 inches of mercury vacuum and 8 pounds per square inch gauge?
9. If a 15-pound weight is placed on an area 2 by 3 inches, what is the pressure in pounds per square inch absolute?
10. If the head pressure is 85 pounds per square inch gauge, what is the total force on one face of a circular disk 5 inches in diameter?
11. What is the average temperature desired in a domestic cabinet?
12. What determines the temperature at which a refrigerant will vaporize?
13. Express standard atmospheric pressure in pounds per square foot.
14. Should refrigerants be operated at temperatures above or below their critical temperature?

15. What is dry ice?
16. Should dry ice ever be put in a sealed container? Why?
17. What is the relative heat absorbing value of 1 pound of dry ice as compared to 1 pound of water ice?
18. Does color affect the amount of heat absorbed by a surface by radiation? How?
19. Name a condition which illustrates the principle of convection.
20. Which material conducts heat the fastest, glass or copper?

1-49. ENTHALPY

Enthalpy is the total amount of heat in one pound of a substance calculated from an accepted temperature base. The temperature of 32°F is the accepted base for water and water vapor calculations. For refrigerator calculations, the accepted base is -40°F.

Example #1 -- refer to Fig. 1-9, page 22

What is the enthalpy of water at point B?

Answer: O Btu because it is at 32°F.

Example #2

What is the enthalpy of water at Point C?

Answer: 180 Btu, which is the difference between the Btu at point B which is 180 and point C which is 360 Btu.

1-50. ENTROPY

Entropy is the heat available measured in Btu per pound degree change for a substance.

Entropy calculations are made from generally accepted temperature bases. For heating and steam power using water as the medium, the accepted base is 32°F. For domestic and most commercial refrigeration calculations the base is -40°F. For research and very low temperature work, a base of a lower temperature may be selected.

Entropy is used only in engineering calculations, and entropy tables have been worked out and are contained in most engineering handbooks.

1-51. CRYOGENICS

The term cryogenics as used in refrigeration work, refers to very (ultra) low temperature conditions.

It may refer to mechanism for producing temperatures approaching absolute 0. It may refer to storage devices for liquefied gases, also to insulation for very low temperature containers or cabinets.

Chapter 2

REFRIGERATION MATERIALS SERVICE TOOLS

The refrigeration serviceman's job consists mainly of performing rather basic mechanical operations using common materials and tools. However, the success of the serviceman will depend greatly upon his knowledge of the perfection and qualities of the materials used and his skill in performing tool operations accurately.

The content of this chapter is planned to give the necessary knowledge concerning both materials and the correct way to perform refrigeration service tool operations.

2-1. TUBING

The tubing used in all domestic refrigeration work, with the exception of some absorption machines, is specially annealed copper tubing. The purpose of the annealing is to make the copper flexible and to adapt the tubing for flaring and bending. The tubing is also "dehydrated" to free it of moisture. This drying is done by the manufacturer; the tubing is then sealed at the ends by pinching and soldering. The tubing is also deoxidized, that is, the copper is prevented from oxidizing as it is being made.

The tubing may be obtained in sizes from 3/16 in. to 3/4 in. in outside diameter and in 50 and 100 foot lengths although some companies furnish it in as low as 25 foot lengths. When ordering tubing, be sure that dehydrated, annealed and seamless tubing is specified.

The standard wall thickness for soft copper tubing is .035 inches although some of the smaller sizes are also

Deoxidized and Dehydrated

OD	Wall Thickness	Pds. per foot
1/8	.030	.0347
3/16	.030	.0575
1/4	.030	.084
5/16	.032	.109
3/8	.032	.134
1/2	.032	.182
5/8	.035	.251
3/4	.035	.305

2-1. A table showing soft copper tubing sizes O.D.; also thickness and weight.

available in a .030 inch and .032 inch wall thickness. See Figure 2-1.

Copper tubing may be work hardened, which means that the tubing will harden if it is bent or hammered. This hardening action may be caused by handling of the tubing and may produce hard spots which may cause cracks when the tubing is flared. Excessive

bending of the tubing may cause it to suddenly buckle or flatten. Work hardened tubing may be softened by heating it to a blue surface color and allowing it to cool. This heat treatment is called annealing.

HARD COPPER TUBE SPECIFICATIONS, TYPE-L
(for interior service only)

Nominal Size	Actual OD	Wall Thickness
1/4	3/8	.030
3/8	1/3	.035
1/2	5/8	.040
5/8	3/4	.042
3/4	7/8	.045
1	1 1/8	.050
1 1/4	1 3/8	.055
1 1/2	1 5/8	.060
2	2 1/8	.070
2 1/2	2 5/8	.080
3	3 1/8	.090
3 1/2	3 5/8	.100
4	4 1/8	.110

2-2. A table showing hard copper tubing type L sizes O.D.; also wall thickness.

Hard drawn copper tubing, which comes in straight lengths rather than in rolls, is used in many commercial and air conditioning installations particularly in installations requiring sizes over 1/2 inch. Fittings used with this tubing or pipe are of the streamline type and are hard soldered. The wall thickness of the pipe varies with the diameter. See Figures 2-2 and 2-3 for a table of tubing size and wall thickness. Hard drawn pipe is either capped or plugged when purchased, to keep it clean and dry.

2-2. TUBING FITTINGS

There have been many different fitting designs on the market, but the accepted standard for refrigeration fittings is a forged fitting using either pipe thread or Society of Automotive Engineers (S. A. E.) National Fine Thread. See Figure 2-4. The fittings are usually drop forged brass and are accurately machined to form the NF threads, the NP threads, the hexagonal shapes for wrench purchase and the 45 degree flare for fitting against the tubing flare. These threaded fittings must be carefully handled to prevent injury to the threads or the 45 degree flare. These fittings slowly discolor in use. They can be brightened by buffing or dipping in a 10% solution of hydrochloric acid. Use goggles when using the acid solution.

All fittings sizes are based on the tubing size to which the fittings are attached. A 1/4 in. flare unit which fastens 1/4 tubing to a flared fitting

HARD COPPER TUBE SPECIFICATIONS, TYPE-K
(heavier wall for exterior and interior service)

Nominal Size	Actual OD	Wall Thickness
1/4	3/8	.035
3/8	1/2	.049
1/2	5/8	.049
5/8	3/4	.049
3/4	7/8	.065
1	1 1/8	.065
1 1/4	1 3/8	.065
1 1/2	1 5/8	.072
2	2 1/8	.083
2 1/2	2 5/8	.095
3	3 1/8	.109
3 1/2	3 5/8	.120
4	4 1/8	.134

2-3. A table showing hard copper tubing, type K, sizes O.D.; also wall thickness.

has 7/16 NF threads and a 3/4 opening wrench is used to turn it. Wherever annealed copper tubing is attached to a fitting, the flared type of seal is usually used. This practice is conventional throughout the industry in the smaller units. A later trend is a soldered connection between the fitting and tubing, Figure 2-5. The correct method of installing tubing is to install it in such a way that there is no extra strain on the tubing when installed. Horizontal loops are used to keep vibration from cry-

REFRIGERATION FITTINGS (FLARED TYPE)

Sizes are based on the Outside Diameter of Tubing

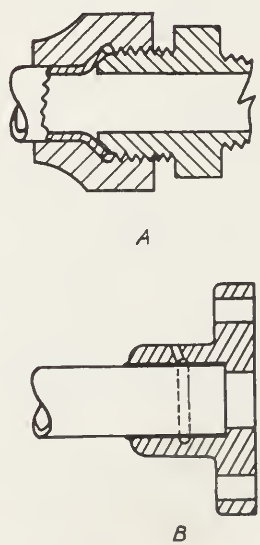
Name and Description	1/4"	5/16"	3/8"	7/16"	1/2"	5/8"
Nt Forged	X	X	X	X	X	X
Uion (Threads same size)	X	X	X	X	X	X
Hlf Union (1/8" Pipe)	X	X				
Hlf Union (1/4" Pipe)	X	X	X	X		
Hlf Union (3/8" Pipe)					X	
Hlf Union (1/2" Pipe)						X
Ebow	X	X	X	X	X	X
Ebow (One 1/8" Pipe)	X	X				
Ebow (One 1/4" Pipe)	X	X	X	X		
Ebow (One 3/8" Pipe)					X	
Ebow (One 1/2" Pipe)						X
Te (Threads same size)	X	X	X	X	X	X
Te (One 1/8" Pipe)	X	X				
Te (One 1/4" Pipe)			X	X		
Te (One 3/8" Pipe)					X	
Te (One 1/2" Pipe)						X
Coss	X	X	X	X	X	X
lared Tube Sealing Plug	X	X	X	X	X	X
lared Tube Sealing Cap		X	X	X	X	X
lared Tube Copper Seal Cap	X	X	X	X	X	X
nion (Reducing)	5/16-1/4	3/8-1/4	1/2-1/4	1/2-3/8		
lbow (Reducing)	5/16-1/4	3/8-1/4	1/2-1/4	1/2-3/8	5/8-1/2	
e (Reducing)	5/16-1/4	3/8-1/4	1/2-1/4	1/2-3/8	5/8-1/2	

2-4. Popular refrigeration fittings using standard pipe and National Fine (NF) threads.

allizing the copper which makes it reak. Some tubing fittings have pipe reads on one end. Pipe threads taper /16 in. to one inch.

3. CUTTING TUBING

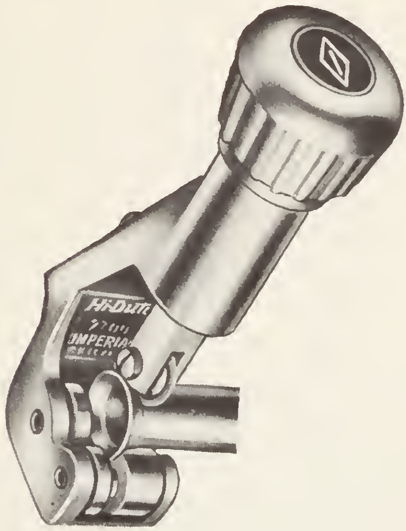
To cut the tubing a hack saw or a be cutter may be used. The tube cutr is used for the annealed copper tubg while the hack saw is used for the rd copper tubings, Figure 2-6. After e tubing has been cut, its ends must b scraped or reamed with a pointed ol to remove any sharp burrs in the d of the tubing. Some tube cutters ve such a tool built into them. If a w is to be used, a wave set blade of teeth per inch is preferable. It is portant that no filings or chips of any nd be allowed to enter the tubing. In



2-5. The two standard methods of joining tubing to fittings. A. Threaded and flanged; B. Soldered.

cutting tubing with a hack saw, hold the tubing in such a manner that chips will not fall into the section that is to be immediately used, Figure 2-7.

If soft tubing is used, pinching the tube eliminates the danger of chips entering the tubing that is not to be immediately used. It also seals the tubing against moisture and protects it for further use. If hard copper tubing is



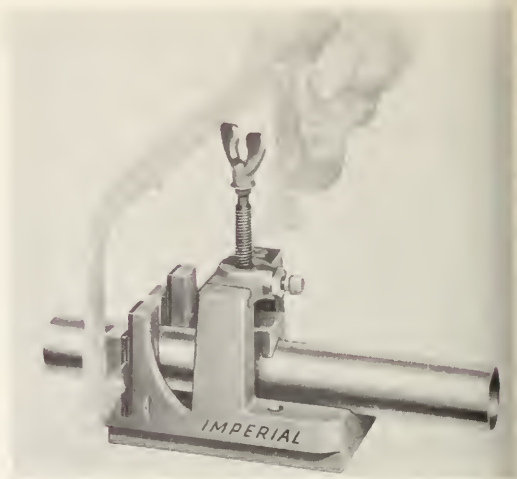
2-6. A tube cutter. The cutter is removing a defective flare.
(Imperial Brass Mfg. Co.)

being used, the tubing ends should be capped or plugged.

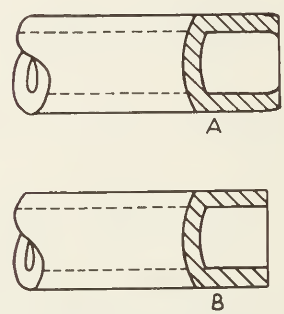
To provide a full wall thickness at the end of the tubing, many service men file the end of the tubing with a smooth or medium cut mill file. Figure 2-8. The tubing should then be straightened to eliminate an off-center flare.

The construction of the flare is also of importance. It is necessary to use the proper tools. These tools must be in good condition to get leak proof flares. Figure 2-9 shows a tool that forms the flare by a spinning action while Figure 2-10 shows a 45 degree flare block.

To produce a flare of the correct size in the recessed tools the tubing



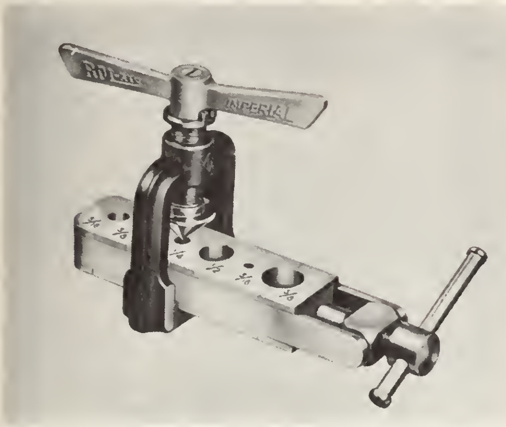
2-7. A sawing fixture used to insure square true ends when sawing tubing.
(Imperial Brass Mfg. Co.)



2-8. How to remove a tube cutter burr from tubing. A. After cutting the tubing with a tube cutter. B. After the tubing was filed with a smooth cut mill file. Note the thinned metal burr after cutting. Note the full wall thickness after filing. A small burr must still be reamed away.

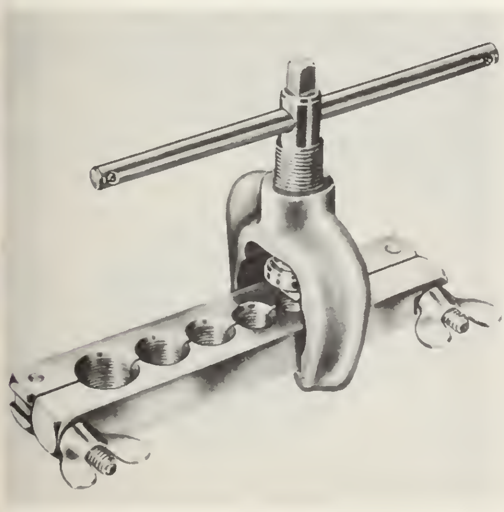
must be inserted into the flaring tool so it extends above the surface of the tool one-third of that distance, which is equal to the depth of the flare, Figure 2-11. The spinner may then be tightened down on the tubing end. The tubing should be worked gradually into a flare, that is, an oscillating motion should be used. First put a drop or two of REFRIGERANT OIL on the spinner where it contacts the tubing; then tighten the spinner one-half or three-quarters of a turn and back it approximately

one-quarter of a turn. Advance it another three-quarters of a turn and again back it one-quarter of a turn. In this way a tubing flare of accurate contour is made with no danger of the tubing cracking.



2-9. A tube flaring tool. The tubing is spun into the correct size flare by the burnished coves on the 90° cone.
(Imperial Brass Mfg. Co.)

If the serviceman prefers, he may, when making the flare, spin the flare not quite to its full contour but only shape it to about seven-eighths of its full position so that when the tubing is tightened into its fitting the flare will assume the shape of the fitting. Under no circumstances tighten up the spinning tool too much because this will thin the wall of the tubing at the flare and weaken it considerably. See Figure 2-12.

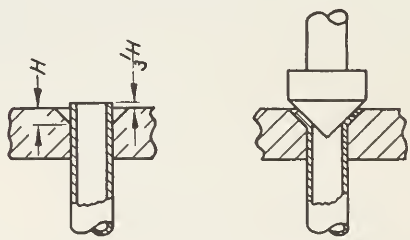


2-10. A split flare block flaring tool. Note the 45° chamfer in the anvil.
(Duro Metal Products Co.)

It is needless to say that when making a flare, the first step is to put the nut on the tube before the flare is made because it cannot be installed on the tubing after the tube has been flared.

2-4. SINGLE THICKNESS FLARE

The punch and block method of a single flare tubing has long been used in refrigeration work. This flare is called the single flare and is by far the most

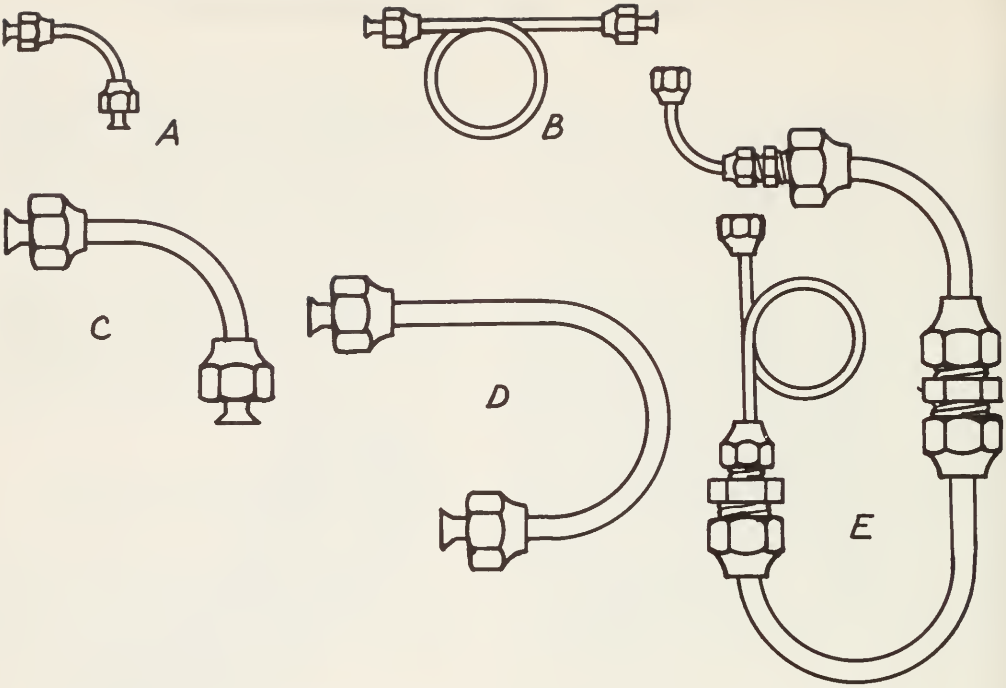


2-11. Recommended allowances for forming a flare using the usual "die block" type of tool.

popular, but certain companies specify what they call a double flare which means that the part of the tubing which forms the flare is folded to form a double thickness.

2-5. DOUBLE THICKNESS FLARE

The double thickness flare is recommended for only large size tubing (5/16 inch and over) and cannot be made very well on the smaller tubing. However, it does make a stronger joint and, if possible, is to be used on joints that need to be extra strong. This flare is made using a double flaring tool; that is, one tool works the tubing into a bulletlike nose, and the other tool bends the tubing in and into the flare, making



2-12. How to make practice flares and test them. A. 1/4" flares; B. 1/4" flares; C. 1/2" flares; D. 1/2" flares; E. The assembled flares ready for pressure testing.

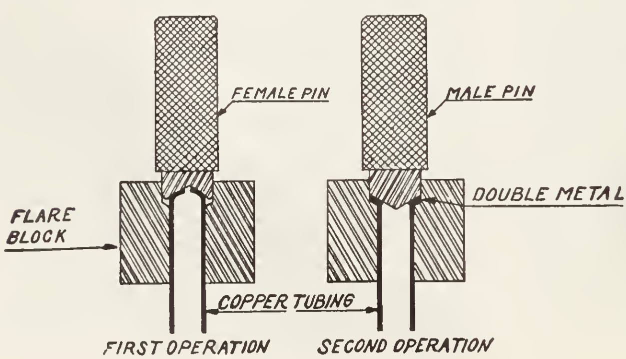
the flare of double thickness, Figure 2-13.

2-6. ANNEALING TUBING

If a flare splits when being made, it may be due to the age of the tubing. Old tubing becomes brittle after a certain period of use and cannot be flared satisfactorily. A remedy is to anneal the tubing by heating to a dull cherry red or blue color and allowing it to cool in air or water. Pounding, rough handling, or bending the tubing tends to harden it.

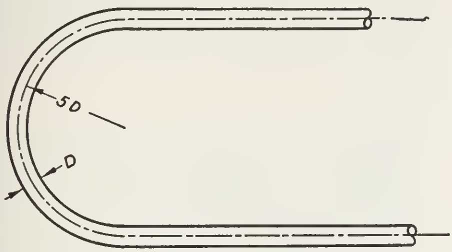
2-7. BENDING TUBING

It takes considerable practice to become competent in bending tubing. For the smaller size tubing such as is used in domestic models, it is not necessary to use special tools to do the bending. However, a much neater job and a much more satisfactory one is obtainable by using special tools. As mentioned before, the tubing should be so bent that it does not apply any strain on the fittings after it is installed. Another important thing is that the tubing at the



2-13. The punch method of forming the double shouldered flare. (Copeland Sales Co.)

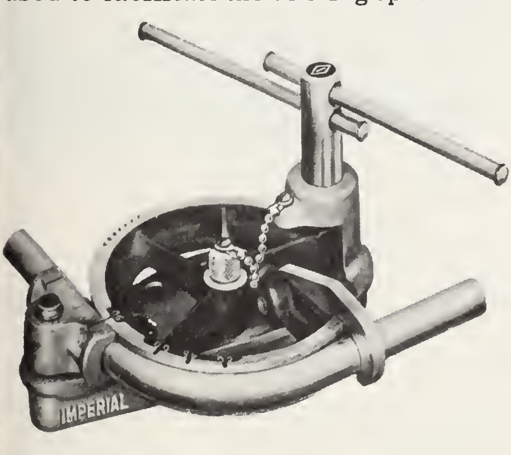
bend should not be reduced in cross-sectional area, that is, be very careful when bending the tubing to maintain the roundness of the tubing and not allow it to flatten out or buckle. It is always wise to bend the tubing into as large a



2-14. The minimum safe bending radius for tubing.

radius as possible because that reduces the amount of flattening of the tubing to a minimum, and it is also easier to bend it that way. The minimum radius in which tubing may be bent is between five and ten times the diameter of the tubing, Figure 2-14. Tube bending should be done quite slowly and carefully. Do not try to make the complete bend in one operation, but bend the tubing gradually so that it may not be ruptured by too sudden a stress.

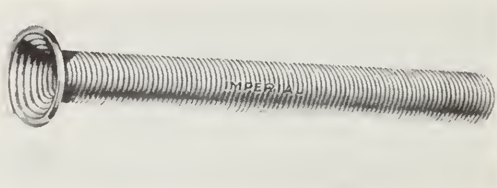
Some special tools which have been used to facilitate the bending operations



2-15. A tube bending tool which prevents buckling of the tube while it is being bent.
(Imperial Brass Mfg. Co.)

are a round block or a short-section of large piping for hand bending; to obtain very accurate work, bending tools may be purchased from manufacturers. Figure 2-15 shows a convenient tool used for bending tubing. An inexpensive coil spring bending tool which is easily carried in a kit and insures against tube buckling is illustrated in Figure 2-16.

These are available in all sizes and are made for both external and internal use. The internal spring is for use near the ends of the tubing or flared tubing, while the external is best used in the middle of long lengths of tubing. A 1/4



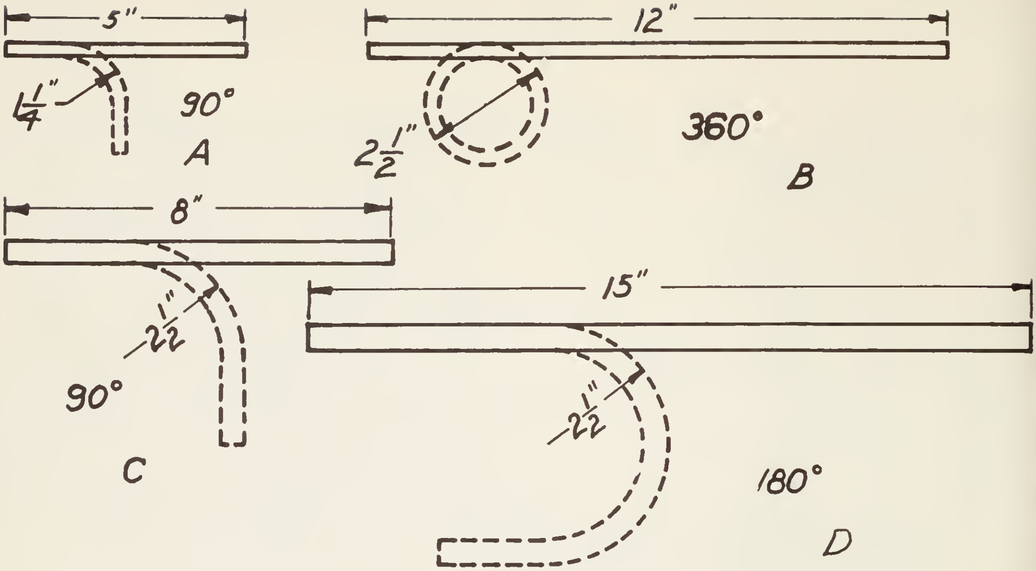
2-16. A coil spring bending tool. It is generally placed on the outside of the tubing.
(Imperial Brass Mfg. Co.)

inch O.D. tube bending spring may be used as an internal spring for 1/2 inch O.D. tubing.

When tubing is bent with a bending spring, it tends to bind on the tubing. It can be easily removed by twisting the spring to cause the external spring to expand or to cause the internal spring to contract. If a bend is to be made near a flare and an external spring is to be used, bend the tubing first. An internal spring can be used either before or after the flaring operation. Figure 2-17 shows some practice bends on 1/4 inch and 1/2 inch copper tubing.

2-8. SOFT SOLDERING

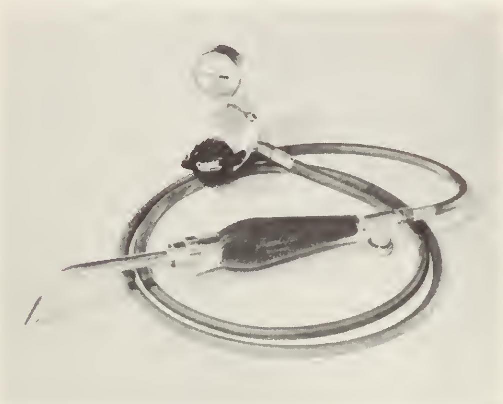
Soldering is becoming more and more a regular service operation. Soldering may be classed as an art, for it is only after very diligent study and



2-17, Practice bends on tubing. A. A 90° bend on 1/4" tubing; B. A 360° bend on 1/4" tubing; C. A 90° bend on 1/2" tubing and D. A 180° bend on 1/2" tubing.

application of soldering theory that real soldering results may be obtained.

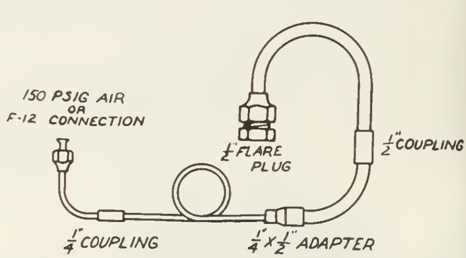
Soldering is applying a molten metal to hot metals that are not molten. It is an adhesion process. The solder flows into the pores of the metals being joined, and as the solder solidifies, a good bond is obtained.



2-18. A portable torch for refrigeration use. It can be used for soldering, light brazing, leak detecting, etc. (Linde Air Products Co.)

Brass parts, copper tubing, fittings, and containers, such as the cooling unit of the refrigerator, are very easily soldered and this facilitates the work of the service man.

Fundamentally, in order to solder, (1) the surfaces to be soldered must be very clean; (2) a good clean flux must be used; (3) and a source of heat of sufficient quantity must be on hand. It must be understood that a non-corrosive flux will not clean a metal. This flux can only keep a metal clean once it has been cleaned by filing, scraping, using steel wool, wire brushes, etc. The parts must have all the grease, dirt and oxides removed from the surfaces being soldered. The good soldered joint is the lap type joint.



2-19. A tubing assembly for determining quality of soft soldering and silver brazing.

A 50 per cent tin and 50 percent lead solder is usually satisfactory for soft soldering, except on cooling coils and

1

Cut tube to length and remove burr with file or scraper.

2

Clean outside of tube with sandpaper or sandcloth.

3

Clean inside of fitting with wire brush, sandcloth or sandpaper.

4

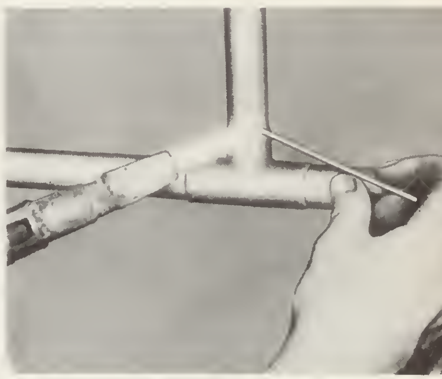
Apply flux thoroughly to inside of fitting.

5

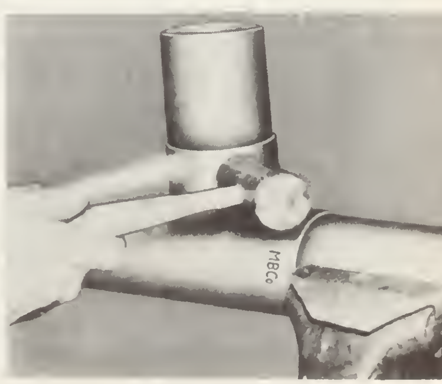
Apply flux thoroughly to outside of tube—assemble tube and fitting.

6

Apply heat with torch. When solder melts upon contact with heated fitting, the proper temperature for soldering has been reached. Remove flame and feed solder to the joint at one or two points until a ring of solder appears at the end of the fitting.



2-20. The correct steps to be followed when soft soldering copper tubing. (Mueller Brass Co.)



7

Tap larger sized fittings with mallet while soldering, to break surface tension and to distribute solder evenly in joint.

their connections. However, solders containing as much as 95 per cent tin are now being recommended for refrigeration work on cooling coils subjected to temperatures below 30 degrees F.

A portable torch, Fig. 2-18, is a practical tool to use for heating surfaces to be soldered. The gas that is recommended for this type of torch is acetylene (Prest-O-Lite). The flux recommended for this type of work is one which has no corrosive properties. A very satisfactory flux may be made of alcohol and rosin. If an acid flux is used in this work, it tends to corrode the fittings and makes them unsightly and hard to work on later.

An important fundamental of good soldering is that the metal being joined must be hot enough to melt the solder. This is the only way the solder will go into the pores of the metal. The heat should be applied to the metal to be soldered; then touch the solder to the metal. If the parts to be soldered are of the correct temperature, cleaned and fluxed, the solder will flow quickly over the surface. Do not heat the solder with the torch.

When joining tubing and tubing fittings by soldering, one must clean the exterior of the tubing and the interior of the fitting thoroughly. Rolls of sand cloth are a good cleaning means. Internal and external brushes are also used considerably. Figure 2-19 illustrates a tube soldering unit that can be connected to a Freon-12 cylinder or compressed air line and checked for leaks. When soldering tubing certain definite steps should be followed in a definite order. Figure 2-20 illustrates the correct procedure.

Soldering coppers are frequently used to perform some of the lighter soldering tasks. These coppers come in sizes from 1 to 4 pounds. The copper must have a thin coating of solder on the surface of the point. This "tinning" of the copper is accomplished as follows:

1. Remove the oxide from the point with a smooth file or sandpaper
2. Heat the copper
3. Sand the point of the copper
4. Immerse the point in flux
5. Rub the point of the copper in solder placed in the hollow of a sal ammoniac block (a flux)

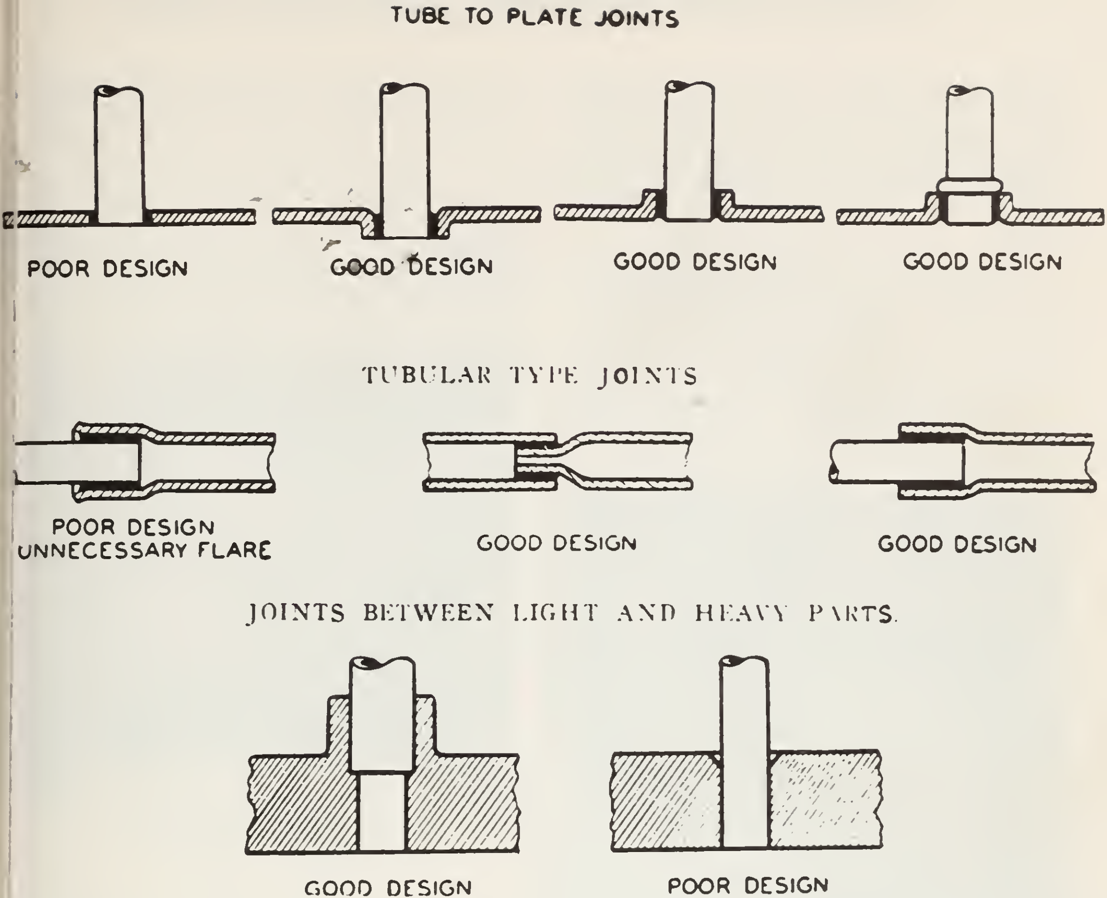
Wire solder is usually the most convenient to use because of the difficulty of getting at the soldering surfaces, and the ease of application of the wire solder. To clean the surfaces previous to the soldering, a dry abrasive should be used, such as sandpaper. Do not use emery cloth or emery paper on the surface under any conditions. While soldering, a helpful procedure is to "wipe" the surfaces after putting some solder on them; use a cloth, a brush, or the solder wire itself. This action will remove any dirt and will help tin the surfaces.

2-9. REPAIRING THREADS

Occasionally the threads of a fitting or fixture may become worn to such an extent that they will not remain leakproof, especially pipe threads. A very convenient and rapid remedy for this is to coat the threads with solder and then remove the excess solder by sharply rapping the fitting while it is still warm. The threads will then be coated with a thin film of solder which will usually remedy the trouble.

2-10. SILVER BRAZING

One of the best methods of connecting parts together in a leak-proof manner and to provide maximum strength is to silver braze the joint. These joints are very strong and will stand up under the most extreme temperature conditions. Silver soldering, or silver



2-21. Some recommended designs which may be successfully silver soldered. (Handy & Harman)

brazing as it is more correctly called, can be easily done if the correct procedure is followed. The points to be remembered are as follows:

a. Clean the joints mechanically

b. Fit the joint closely and support the joint

c. Apply the flux to match the silver brazing alloy; Follow the instructions on the container

d. Heat evenly to the recommended temperature

e. Apply the silver solder as directed

f. Cool the joint properly

g. Clean the joint properly and thoroughly

An oxy-acetylene torch is an excellent heat source for silver brazing. There are various silver alloys on the market. Most of these have a 35% to 45% silver content. Contact your local welding supply house for suitable silver soldering and brazing supplies. This material usually melts at 1120 F. and flows at 1145 F. The part to be soldered or brazed must be made to fit accurately and must be cleaned. Any external surface should be cleaned to remove dirt. A fine grade of steel wool is considered good. Internal circular surfaces can be cleaned with clean wire brushes or steel wool rolled on a rod or by using a clean drill.

The parts must have contacting surfaces of sufficient size, such as a tube sliding into a fitting (not a drive fit) to get a strong fit, Figure 2-21. The contacting surfaces need not be very large (three times thinnest section). If the

parts are dented or are out of round, these faults must be corrected before the brazing is done. It is important to support the parts securely during the operation so no movement will take place.

It is important to make sure that no flux enters the system during the brazing operation as it cannot be easily removed. This overfluxing can be avoided by applying the flux to the surface that is to slide into the part. The excess flux will then stay on the outside.

2-22. Silver brazing copper tubing to a compressor dome. Note carbon dioxide connection. (Handy & Harman)

The heating of the joint must be very carefully done. Carbon dioxide or nitrogen should be circulated through the refrigerator system during any soldering operation on a complete mechanism to prevent an explosion, Figure 2-22. Caution: NEVER USE A REFRIGERANT OR COMPRESSED AIR. The flux behavior is the best way to learn what the temperature of the joint is as the heating progresses. Keep the joint covered with the flame all during the operation to prevent air getting to the joint. The flux will dry out; the moisture (water) will boil off at 212 F.; then the flux will turn milky in color. Next it will bubble at about 600 F., following this it will turn into a clear liquid at about 1100 F. This temperature is just short of the brazing temperature. The solder itself melts at 1120 F. and flows at 1145 F. A torch tip several sizes larger than the tip used for soft soldering should be used so be sure to heat BOTH pieces which are to have the silver alloy adhere to them. Larger torch tip sizes are recommended to allow a

2-23. Silver brazing a copper tubing connection. Note the oxy-acetylene torch and the careful mounting of the parts being brazed. (Handy & Harman)

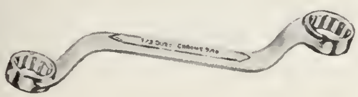
soft large quantity of heat without excess pressure or "blow." A slight

2-24. A set of socket wrenches and handles. (Snap-On Tools Corp.)

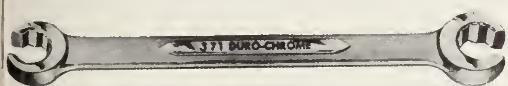
leather on the inner cone is recommended. Figure 2-23.

2-11. CLEANING THE BRAZED JOINT

It is necessary to thoroughly wash and scrub the completed silver brazed joint. Use water. Any flux left on the metals will tend to corrode them and the residue flux may also temporarily



2-25. An alloy steel box wrench which has 12 points for use in cramped space.



2-26. A flare nut wrench. The open jaw permits mounting the wrench on the nut with the tubing in place. (Duro Metal Products Co.)

stop a leak which will show up later.

The joint may be cooled quickly or slowly. Cooling with water is permissible. This water may be used to wash the joint at the same time. Visual inspection of the joint will quickly reveal any places where the silver alloy did not adhere, but it is advisable to watch for this adherence and make any corrections during the brazing operation.

2-12. WRENCHES

A serviceman uses many wrenches of several types and sizes. All wrenches must be made of good alloy steel, properly heat treated, and accurately machined and ground to fit the assembly devices. The wrench must fit the nut or bolt head accurately, and it must fit as much of the hexagon as possible. For these reasons, the wrench types are listed in their order of preference:

1. Socket Wrenches
2. Box Wrenches
3. Open End Wrenches
4. Adjustable Wrenches

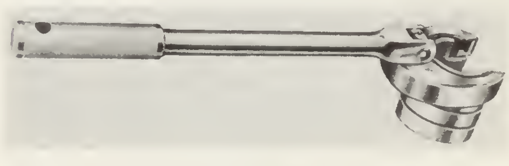
2-13. SOCKET WRENCHES

If the unit or socket does not have any obstructions over it, the six or twelve point socket is the best wrench to use. These sockets are usually made of chromium-vanadium steel and are turned by handles that have a 1/4 in. square, a 3/8 in. square, or 1/2 in. square drive, Figure 2-24. The handles come in a variety of designs: Swivel handles, T-handles, Ratchet handles, Speed handles, Torque handles, etc.

Socket wrenches are more usable if they are double broached (12 point). Such a socket is easier to use if the handle must be operated in a small or restricted space.

2-14. BOX WRENCHES

When the nuts or bolt heads are in close quarters and one cannot use the socket wrench, the box wrench is an excellent tool. These box wrenches are usually 12 point and provide a powerful non-injuring grip, Figure 2-25.



2-27. A ratchet type flare nut wrench which may be used where there is little space for movement of the handle.
(Tubing Appliance Co., Inc.)

A very useful wrench for flare nuts is the double broached box wrench made

with an opening in the box ends to permit one to fit the wrench over the tubing, Figure 2-26. Box wrenches having flat and 15 degree handles are necessary to complete a kit. Figure 2-27 illustrates a ratchet type flare nut wrench.

2-15. TORQUE WRENCHES

All materials are elastic. The cast iron and hardened steel used in the construction of compressors are elastic to a degree. In tightening bolts, nuts, and other attachments on compressor parts

2-28. Torque wrench.
(Duro Metal Products Co.)

and assemblies, it is important that the degree of tightness be measured in order not to distort or cause a misalignment of parts. In order to measure the degree of tightness, a torque wrench is used, Figure 2-28.

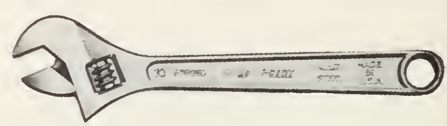
These wrenches are usually wrench handles only and are made to receive sockets of various sizes. The handle is equipped with a graduated dial or pointer which is calibrated in foot pounds or inch pounds (to be technically correct it should be called pounds feet and pounds inches). To use the wrench the operator fits the socket to the nut, then draws up the tightness until the wrench indicator shows the tightness prescribed. Service manuals list the recommended torque (twist) for various parts and fittings to give a snug fit and still not cause excessive distortion.

Torque is calculated by multiplying the length of the handle in feet by the pull in pounds applied to the handle (foot pounds). Inch pounds is calculated by multiplying the length of the handle in inches by the pull on the handle in pounds.

2-16. OPEN END WRENCHES

These wrenches can slide on the nut or bolt head from the side and are used in close quarters and on unions and the like where the socket wrench and the box wrench cannot be placed on the assembly device.

End wrenches should not be used when the jaws are spread or when there are burrs. It is also recommended that end wrenches used in servicing work have a wide jaw, or they will have a tendency to bite into the soft brass parts. Some popular sizes for wrenches are: 1/2 inch across flats for 5/16 inch N.C. and N.F. cap screws. These cap screws are commonly used on compressors, expansion valves, float valve headers, etc. The 7/16 in. across flat wrenches for 1/4 in. screws and bolts are needed for float valve headers, etc. The 3/4 in. across flats are used for 1/4 in. flare nuts which use 7/16



2-29. An open-end adjustable wrench. This very popular wrench must be carefully used to prevent injury to the assembly device and to the wrench.
(Snap-On Tools Corp.)

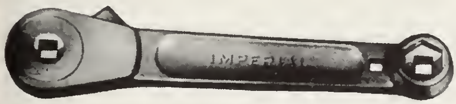
in. 20 N.F. threads. The 1 in. across flat end wrenches fit the 1/2 in. flare nuts which use 3/4 in. 16 N.F. threads.

2-17. ADJUSTABLE WRENCHES

Wrenches with an adjustable opening between the jaws have long been popular. One wrench can be used on a number of different sized nuts or bolt heads. However, the adjustable feature usually

results in one relatively weak jaw which soon goes out of alignment; and also hurried work sometimes means that the wrench will not fit tightly, resulting in a ruined wrench, bruised hands, and a ruined nut or bolt head, Figure 2-29.

Adjustable wrenches are necessary in the kit because of the odd sizes found in this work, but it is best to use the other wrenches unless the adjustable wrench is fitted tightly to the nut. The reason for this recommendation is that adjustable wrenches are much more expensive and are sometimes used when not correctly adjusted to the nut, tending to abuse it.



2-30. A service valve ratchet wrench. The left hand opening is a 1/4 in. square, the right hand a 1/4 in. square with a 1/2 in. hexagonal socket. The other square is a 3/16 in. opening.
(Imperial Brass Mfg. Co.)

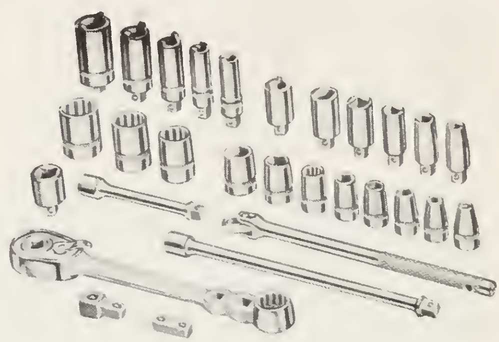
2-31. A special service valve wrench. Note the fixed end for "cracking" purposes and the reversible ratchet end for quick control of valve stems. The fixed end has openings for three different size valve stems.
(Duro Metal Products Co.)

It is important to use wrenches in such a way that they fit completely on the nut or bolt. One should always pull on a wrench rather than push on it, otherwise sudden loosening may cause serious injury to the hand.

2-18. SERVICE VALVE WRENCH

The service valve stems are usually constructed with a square end milled on the valve shaft and need a special wrench to manipulate them. This tool usually has a ratchet and a fixed end for this kind of work. It may be mentioned here that, when cracking valves, the fixed end only should be used; when opening and closing valves through any appreciable distance the ratchet end may be used, Figure 2-30.

Some service valve wrenches have a reversible ratchet which enables the



2-32. A set of socket wrenches and handles for refrigeration work. The top row are gland sockets and valve stem sockets. The middle row are 12 point and 6 point sockets.
(Duro Metal Products Co.)

operator to reverse the turning without removing the wrench from the stem, Figure 2-31.

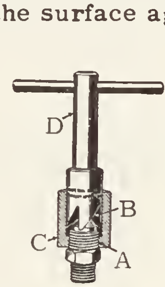
2-19. SERVICE VALVE WRENCH ADAPTERS

Many companies use valve stems other than the 1/4 inch square; some valve stems are constructed in such a manner that the milled end is inside the valve body, necessitating a socket wrench to manipulate it. For these reasons adapters are available in the various sizes. The male, or drive, part of the socket is usually 1/4 in. square although there are a few which use a larger drive (9/32 in.). The socket, or opening which fits the valve stem, comes in five sizes: 3/16 in., 7/32 in.,

1/4 in., 5/16 in. and 3/8 in. These sockets are usually made with eight points to simplify their use. Most of the valve stems have internal packing gland nuts, and special sockets must be used. Some Frigidaire and Norge valves are examples. It is best to obtain these special sockets with ball-bearing grippers to prevent losing them when working in difficult positions. Figure 2-32 illustrates these special sockets.

2-20. FITTING RESURFACERS OR REFACERS

After a fitting has been used for a number of times and tightened and loosened repeatedly, the 45 degree flare surfaces become worn. Rough handling may also abuse the 45 degree surface. To true up the surface again, a special

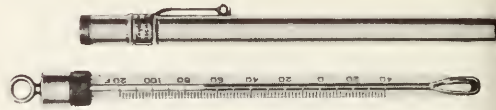


2-33. A fitting reamer set. A. Flared end of fitting; B. 45° reamer blades; C. Adapter for each size of fitting; D. Reamer handle.
(Imperial Brass Mfg. Co.)

tool may be used. This tool consists of a 45 degree end reamer built into a special jig with adapter threads for every size fitting. A T-handle is used to manipulate the reamer. One form of this tool also recuts the threads. Badly worn fittings should always be replaced rather than repaired. Figure 2-33 illustrates a fitting reamer set. One should never reverse the turning of the reamer as the action will dull the cutting edges.

2-21. THERMOMETERS

Two tools that the service man must depend on are the thermometer and gauge set. The thermometer is used to check the cooling unit temperature, the refrigerator cabinet temperature, and the condensing unit temperature. To determine whether the thermometer is

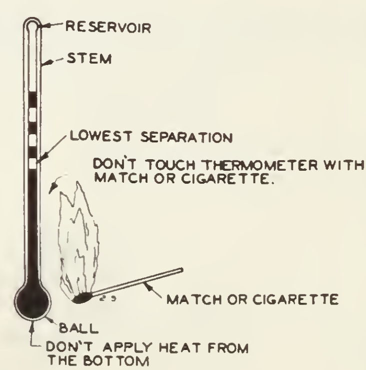


2-34. Stem type refrigeration thermometer with pocke carrying case.
(Taylor Instrument Co.)

accurate, an ice and water bath may be used, and the thermometer should check within 1 F. of 32 F. Usually the thermometer carried by refrigerator servicemen will not go up to 212 F., therefore, the ice bath is the only check that can be easily used, Figure 2-34.

Many types and sizes of thermometers have been developed for the refrigeration service and installation man. Probably the most popular is the glass stem type mounted in a metal case that is equipped with a pocket clip to permit it being easily carried in a pocket.

The glass stem thermometers usually read from -30 F. to 120 F. in 2 F



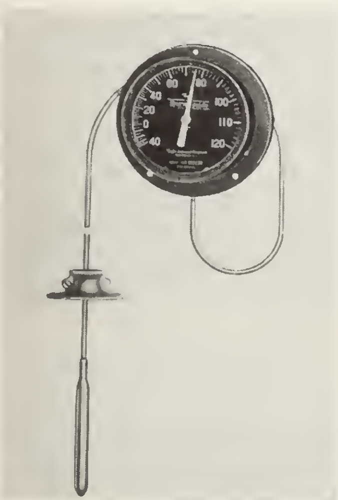
2-35. One method that can be used to connect a brea in the liquid column of a glass stem thermometer.
(White-Rodgers Electric Co.)

raduations. The tube may contain ither mercury or a red fluid. The 1ercury-filled thermometer is faster, ut it is harder to read. Some ther-1ometers have a special magnifying ront built into the glass to magnify 1e liquid level to aid in reading.

Occasionally, the fluid in the col-mn will separate. The best way to 1ake the column a solid column of iquid again is to cool the bulb with a mall quantity of liquid Freon-12 spray-d on it. The column will shrink into he bulb; and when it re-expands, the reak will have disappeared. If the 1ercury is frozen into a solid the ther-1ometer will break.

Another way to connect the column hen a break occurs is to heat the hermometer as shown in Figure 2-35.

Metal clips are available to fasten hese thermometers to coils and tubing or accurate temperature measuring.

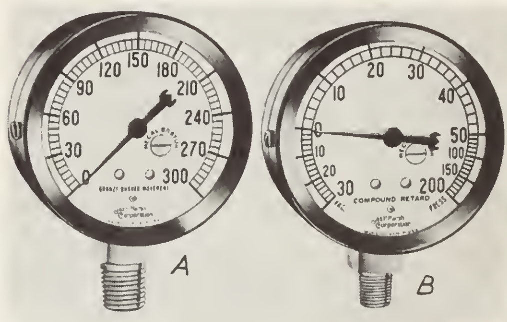


2-36. A dial type thermometer with a remote sensitive bulb. Note the range is from —40 F. to 120 F. (Taylor Instrument Co.)

Dial thermometers are also used extensively. They are operated either by a bi-metal strip or by a bellows charged with a volatile fluid. Some of the dial thermometers have a remote sensitive bulb connected to the bellows by means of a capillary, and some are equipped with an adjusting screw to enable one to reset them if they start to read inaccurately. Figure 2-36.

2-22. GAUGES

Inasmuch as the pressure gauges that the serviceman uses are the instruments whereby he determines exactly what is happening inside the system, it is evident that these gauges must indicate correctly. This necessitates very accurate gauges and a periodic recalibrating of these gauges

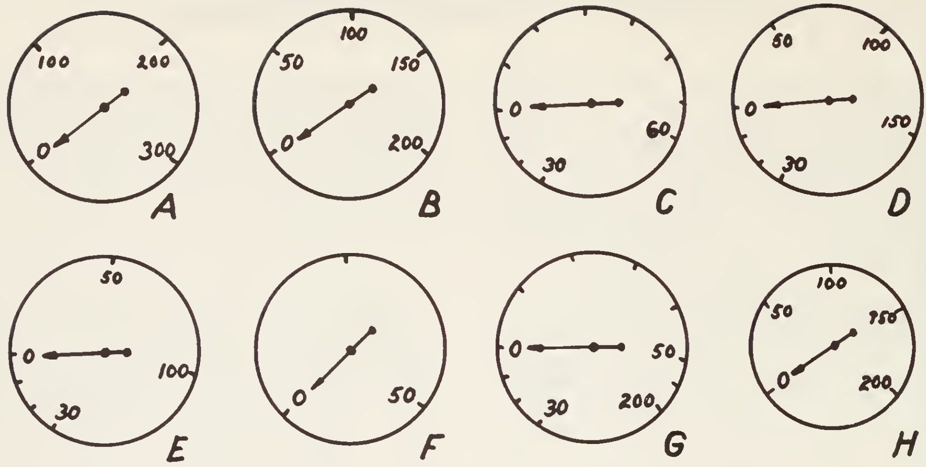


2-37. Pressure gauges for servicing refrigerators. A. The high pressure gauge. B. The compound or low pressure gauge. (Marsh Instrument Co.)

to reset them to their original accuracy. The two gauges most used are the high pressure gauge used on the high side of the system and the compound gauge used on the low side of the system. These two gauges are calibrated quite differently. See Figure 2-37, A and B.

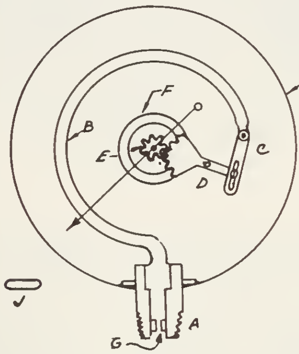
The high pressure gauge (A) has a single continuous scale reaching from 0 to 300 usually. The compound gauge (B) measures pressures both above atmospheric and below atmospheric.

There are a large number of different dial calibrations on the market, Figure 2-38. The high pressure gauge scale is usually in either 2 lb. or 5 lb. graduations, while the compound gauge scale is either in a 1 in., 2 in. or 5 in.



2-38. Several types of gauge dials. A, B, F, and H are pressure gauges. C, D, E, and G are compound gauge

graduations below atmospheric pressure and as above for pressures above atmospheric. Some gauges use a retarder to permit accurate readings in the usual operating range by using an extra spring at pressures above normal. These gauges are easily recog-



2-39. Internal construction of a pressure gauge. A. Adapter fitting, usually 1/8 in. national pipe; B. Bourdon tube; C. Link; D. gear sector; E. pointer shaft gear; F. calibrating spring; G. restrictorl H. case. A bezel fastens the crystal to the case and a dial completes the gauge. All the bearings are very delicate and the gauge must be handled with the greatest care. J. is the cross section of the Bourdon tube.

nized by the change in graduations at the higher readings of the positive pressure scale.

The gauges are constructed using a Bourdon tube as the operating element. This Bourdon tube is a flattened copper tube sealed at one end, curved, and soldered to the gauge fitting at the othe end, Figure 2-39. A pressure rise i the Bourdon tube will cause it to ten to straighten out. This movement wil pull on the link, which will turn th gear sector contra-clockwise and th pointer shaft will then turn clockwis moving the needle likewise.

Instruments have been designed t calibrate gauges accurately; any sho that uses a large number of gauges o is remotely situated should have one c these instruments on hand for calibra tion. These instruments are usuall built on the basis of dead weights fo calibration above atmospheric pres sure and a mercury column indicat for pressures below atmospheric, o vacuum.

The high pressure gauges have range as shown, of 0-300 psig pres sure, but this does not protect th gauges from being harmed at lowe pressures. A rapidly fluctuating pres sure at any pressure will soon harı the gauge. A sudden release of 300 ps into the gauge will also injure it. Th most popular gauges have a 2 1/2-ir dial and use a 1/8-in. pipe, mal thread. However, many have 1/8-ir pipe female thread. A servicema should use another fitting 1/8-in. pip male by 1/8-in. female to protect th gauge threads. The compound gaug

pecially should be protected from y abuses and sharp pressure fluctuations. These gauges should be calirated at least once every month. By calibration is meant that they should be checked on a machine using a master gauge. They must be checked over their full range or scale.

The compound gauge may be obtined in various calibration ranges

Refrigerant	Viscosity SSU 100°F	Floc Test °F	Corrosion Cotton Strip at 212°F	Pour Test ASTM (Max. °F)	Dielectric Strength Volts, Min.
SO_2 (R_e)	75-85		No	—45	25,000
SO_2 (R_e)	95-115		No	—40	25,000
Methyl Chloride (R_e) F-12 (R_e) F-21 (R_e) SO_2 (R_o) F-114 (R_e)	150-160		No	—35	25,000
F-22 (R_e) (Low Temp)	150-160	—70	No	—35	25,000
	190-210		No	—30	25,000
Methyl Chloride (R_o) F-21 (R_o) F-12 (R_o) F-114 (R_o)	280-300		No	—25	25,000
F-22 (R_o) (Low Temp)	280-300	—50	No	—25	25,000

SSU means Standard Sayboldt Unit (Sayholdt Universal Seconds) and is the time required for a certain oil quantity to flow through a certain size opening, therefore, the higher the number the "thicker" the oil.

Floc test is the temperature at which wax separation occurs.

Pour test is the American Society of Testing Materials standard on the maximum temperature before the material becomes fluid.

Dielectric strength is a test of the resistance of the oil to electrical flow. This resistance is specially important in hermetic units and is very important in all systems.

R_o is the symbol for rotary compressors and R_e is the symbol for reciprocating compressors.

40. Refrigerant oil properties required for various refrigerants using different compressors and operating at typical temperatures.

ich as 30 in. Vac-0-60 psig, 30 in. ac-0-90 psig and 30 in. Vac-0-120 ig. Compound gauges should never used on the high pressure side of a stem. When using a compound gauge machines, in which the high pressure ay back up through the compressor or lance through the refrigerant conol while the compressor is stopped, a -in. Vac-0-200 psi gauge should be ed.

One company is now marketing a ecial compound gauge which, in addion to the usual pressure calibration, 30 in. Vac-0 psi, has three additional scales which give the evaporating temperature corresponding to the various pressures for such refrigerants as sulphur dioxide, methyl chloride, and Freon-12. This extra scale makes it unnecessary to refer to pressure temperature curves or tables for common refrigerants in order to check operating pressures.

2-23. REFRIGERATION OIL

In the mechanical refrigerator the moving parts, of course, must be lubricated with oil in order to have long life and efficient performance. This oil is of special grade, usually rather light, and is specially treated to remove all moisture and corrosive compounds.

Refrigerant oil is especially prepared mineral oil. Special refining precautions must be taken to remove practically all of the wax, moisture, sulphur and other impurities. Most refrigerant

oils have a foaming inhibitor added.

(One must be very careful to use oils that have a low enough pour point and that there will be no wax separation at the low temperature to cause refrigerant control clogging.)

Refrigerant oils are available in several viscosities. Vis cosity is the time in seconds it takes for a definite quantity of the oil to flow through a certain size opening at 100 degrees F. (Sayboldt). Therefore, the lower the viscosity number, the thinner the oil. The six standard viscosities are 75-85, 95-105, 150-162, 192-208, 300-324, and 485-515.

The Freon group of refrigerants uses the thicker oils such as 300-324 and occasionally 485-515 (air conditioning).

Methyl Chloride uses the 300-324 group; sulphur dioxide uses the 150-162 group usually, while the 95-105 group is for low temperature use.

The food freezer and frozen food units need oils that have extra low pour points, and they must have extra low wax contents.

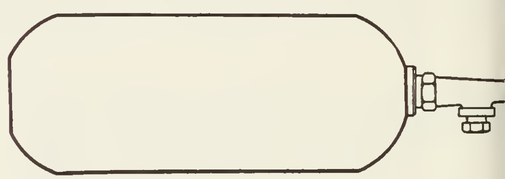
Hermetic system oils must be of the best quality obtainable. These oils must have a minimum of foreign matter, moisture, and wax. The oil cannot have any hydro-carbons that may precipitate on the compressor valves or other parts. The viscosity of the oil must be accurately determined for the temperature ranges to which the refrigerator may be exposed. The oils must have a very low temperature pour point and a very low wax separation point. The accepted method to test an oil for moisture content is the Dielectric Test. This test imposes a 25,000-volt electric pressure on electrodes immersed in an oil sample. If any current flows there is moisture present in the oil and the oil is unfit for refrigeration use. It is highly important that this oil be kept in sealed containers, that it be transferred in chemically clean containers and lines and that it not be left exposed to the air as it will absorb moisture, Figure 2-40. Never refill a refrigerator with used oil. Always use new oil.

The oil (mineral oil) is obtainable in 1-gallon cans, 5-gallon cans, and in barrels. The price varies somewhat with the grades, such as a low pour-point oil is more expensive than one having a higher pour-point value. The pour-point of any oil is the temperature at which it starts to flow. For domestic machines with refrigerant temperatures as low as 0 F. to 5 F., a pour-point of -20 F. is desirable. Always seal an oil container after having drawn some oil from it.

2-24. REFRIGERANT CYLINDERS

Refrigerant cylinders are made of steel. They are usually of one piece construction with one opening for the service valve. The larger cylinders usually have a fuse plug threaded into the concave bottom as a protection against overheating or excessive pressures.

The refrigerant cylinders should be stamped with an I.C.C. stamp (Interstate Commerce Commission) and



2-41. A refrigerant service cylinder. The color code fo cylinder colors is as follows: Silver and black—sulphu dioxide, Orange and black—methyl chloride, Red an black—iso-butane, Yellow and silver—Freon —12.

should also be dated. The cylinde should not be used when the date on th cylinder is more than six years old Refrigerant manufacturers request tha all cylinders be returned to them eac six months or more often in order tha

the valve fittings and the complete cylinder may be carefully checked. This service assures safer cylinders. The service man's cylinders are called 5-lb. cylinders; they are usually equipped with a service valve having a 1/8 in. pipe female connection, Figure 2-41. This size of cylinder is not equipped with a safety fuse plug. The cylinder will hold 5 lbs. of sulphur dioxide, 3 lbs. of methyl chloride, just a little more than 1 lb. of iso-butane (Freezol), and 5 lbs. of Freon -12.

The cylinders for the various refrigerants obviously should not be interchanged; to help prevent this, different colors are painted on the cylinders. Silver and black are used for sulphur dioxide cylinders; orange and black for methyl chloride cylinders; and red and black for iso-butane, while yellow and silver are used for Freon -12. When purchasing refrigerants, 100 and 150 lb. containers should be obtained. This permits a much lower price per pound of the refrigerant. The transferring of the gas from this large cylinder to the service cylinder should be carefully performed and a record kept of how much has been removed. Add 3 per cent to account for gas losses. Service men also use cylinders of the following sizes for large jobs. These cylinders are equipped with safety fuse plugs:

Freon 12	25 lb.		145 lb.
Freon 22	22 lb.		125 lb.
Methyl Chloride	15 lb.	60 lb.	100 lb.
Sulphur Dioxide	25 lb.	100 lb.	150 lb.
Freon 114	25 lb.		150 lb.

A cylinder should be thoroughly rinsed out periodically. Use a moisture absorbent cleaning fluid, as the impurities getting into the refrigerants may be very corrosive to the refrigerating system.

You can tell whether or not there is refrigerant in a cylinder by shaking it and listening to the movement of the liquid or by tapping the sides of the cylinder, which will indicate the level by changing its tone as the pounding passes the liquid level.

The cylinder valves should receive the same care as the service valves of a refrigerator. The valve is a packed, one-way valve; the packing nut should be kept tight unless using the valve. The opening should be sealed with a plug when not in use.

Caution: NEVER FILL A REFRIGERANT CYLINDER COMPLETELY FULL OF REFRIGERANT BECAUSE THE CYLINDER MIGHT BURST DUE TO HYDROSTATIC PRESSURE. THE SAFE LIMIT IS 85 PER CENT FULL. NEVER HEAT A CYLINDER WITH A FLAME; IT MIGHT BURST.

Service tanks should be weighed before and after filling, for in this way the amount of refrigerant in the cylinder may be readily determined. When charging a cylinder, the service cylinder should be placed on accurate scales and only the specified weight of refrigerant charged into it.

2-25. BRINE

Some older refrigerating units have the cooling unit in a brine filled tank. The advantage claimed for these brine tanks is that the quantity of the brine acts as a storage for refrigeration; it will absorb considerable heat between running cycles of operation of the condensing unit, thereby lengthening the interval between cycles of the unit. The term "hold over" is applied to cooling units that are designed to provide refrigeration between running periods of the condensing unit.

2-26. COMPOSITION OF BRINE

The older refrigerators used a calcium chloride (CaCl) brine. This brine was composed of a solution of about 2 1/2 lbs. of CaCl in a gallon of water. Such brine will not freeze above 0 F. Care should be taken when mixing the brine because of the heat generated. Never mix the brine in the cooling unit itself. To help prevent corrosion, a little bichromate of soda is added.

Later models used alcohol or glycerine brine as they have less corrosive actions on the metals. Alcohol and glycerine brine may be used where CaCl has been used if it is desired.

The usual alcohol brine consists of 30-40 per cent alcohol (Formula No. 1) and water. This brine will not freeze above 0 F. Glycerine brine is made of 40-45 per cent glycerine in water solution. This will not freeze above 0 F.

2-27. GASKETS

Because it is impractical to make surfaces being clamped together leakproof and because subsequent warpage would likewise cause the joint to leak, some soft material (gasket) is used to fill the slight imperfections between the surfaces.

Gaskets are used to seal joints between assembled parts to keep the refrigerant from leaking out, to keep the oil from leaking out, and to keep air from leaking into the system. Gaskets are used between the valve plate and the compressor body, and between the valve plate and the compressor head. Gaskets are also used on the crankcase and at the crankshaft seal.

Metal gaskets are very common. Lead is the most popular metal because it is soft and non-corrosive. Aluminum has also been used. Composition gaskets made of plastic impregnated paper are also popular.

These gaskets must not restrict the openings. They must not lose their compressibility, and they must not be thicker than the original gasket.

The surfaces that contact the gasket must be kept free of burrs, bruises, and foreign matter.

2-28. CLEANING

Before any mechanism can be successfully repaired, it must be thoroughly cleaned. Also this same mechanism must be cleaned after it has been repaired. Many methods have been used to clean mechanisms. Some do not do a thorough job, while others are dangerous. A cleaning method must be able to remove oil, grease and sludge. It must not injure the parts and, most important, it must not be injurious to the user. In refrigeration and air conditioning applications, the cleaning method must remove moisture, or at least not add moisture.

There are several classes of cleaning methods:

1. Steam Cleaning: If the parts are exposed to hot water or steam, the grease will become more fluid and will float off the surface. However, steam and hot water will burn one if carelessly used.

2. Caustic Solution Cleaning: When an alkaline is dissolved in hot water, the mixture will remove grease and oil. This solution must be carefully used or one may suffer burns or injured eyes.

3. Oleum or Mineral Spirits: A petroleum product that is very popular is a petroleum derivative that has a flash point of approximately 140 F. (kerosene has a flash point of 130 F.). It cleans well and leaves a nice smudge-free surface. However, there is always a fire hazard in connection with this fluid. It cleans well, but should always be used in small amounts only. It should

be used in self-closing tanks, and the cleaning tank should be exhaust ventilated (hood and an explosion-proof exhaust fan).

4. Carbon Tetrachloride: This is an extremely heavy fluid that cleans grease, oils, sludge, etc.; and it also absorbs some moisture. For many years, it was rated as almost a perfect cleaner. However, medical authorities found that carbon tetrachloride breathing or wetting the skin with carbon tetrachloride affects the kidneys and liver and that this bad effect is accumulative. Breathing even small concentrations of the fumes will eventually make one very ill and may even cause death.

5. Never use gasoline for cleaning. It has an extemely low flash point, and its fumes are heavy and may travel far to ignition sources.

6. Alcohol is a good cleaning fluid. However, it is both flammable and toxic. Special precautions must be taken when using it.

7. Vapor degreasing is a system whereby a cleansing fluid is placed in a tank; the fluid is warmed so that the upper part of the tank is filled with the vapors of the cleaner. Any parts suspended in this cleaning vapor are quickly and thoroughly cleaned. Such a tank must be specially vented.

8. There are several patented cleansing fluids available. One should be sure to read the instructions and to follow them closely.

Refer to Chapter 29 for a more technical explanation of metal cleaning.

2-29. ABRASIVES

Surfaces are cleaned, smoothed or made accurate to size with abrasives. Abrasives are grinding particles attached to paper or cloth by some glue or adhesive. Various abrasive materials are used. Sandpaper was the only abrasive for many years, and it is still excellent for wood finishings or where a dry surface is wanted. Emery, aluminum oxide, and silicon carbide are abrasive materials used today.

Emery cloth is available in different grades. These grades are 0000 (finest), 000 (very fine), 00 (fine), 0 (fine), 1/2 (medium fine), and 1 (medium light).

The silicon carbide abrasives are available as follows: 500 (finest), 360 (very fine), 320 (fine), 220 (medium fine), and 180 (medium).

The aluminim oxides are available as follows: 320 (extra fine), 240 (fine), 150 (medium fine), and 100 (medium).

These abrasives come in 9 in. x 11 in. sheets or in rolls usually 1 inch wide.

When using these abrasives, the paper or cloth is backed by a block made of wood, metal, felt or rubber. Special sanding blocks may also be obtained.

2-30. VALVES

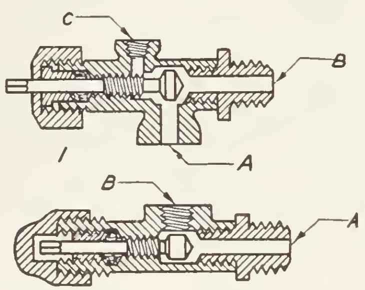
Practically all systems that contain fluids use valves to either manually or automatically control the flow of these fluids. The automatic valves operate on the basis of liquid level changes, on pressure changes, or on temperature changes. Examples of these are the low side float valve, the automatic expansion valve, and the solenoid valve respectively.

However, the service man must also be familiar with the manual valves installed in the refrigerating system. These valves enable the service man to separate the various parts of the system, one from the other, and to install gauges, charge, or discharge a system.

There are several kinds of manual or hand valves in use. These valves may have hand wheels on the stems, but most of them are made in such a way that a valve wrench is needed to turn them. The stems are made of steel or occasionally brass. The body is usually

made of drop forged brass. Packing is installed around the valve stem, and a packing adjusting nut is used to keep the joint from leaking.

The types of valves in use are the one way valve and the two way valve. The one way valve is closed by turning the valve stem all the way in (to the right or all the way clockwise). The two way valve usually closes or shuts off the refrigerant flow in the system when the stem is turned all the way in; while it shuts off the charging, discharging or gauge opening when the valve stem is turned all the way out or all the way contra-clockwise. The valve



2-42. Two typical service valve designs: 1. A two-way valve. A. Opening to compressor; B. To suction line; C. Opening for gauges. 2. A one-way valve. A. To liquid line; B. To liquid receiver.

is open both ways if the stem is turned to be part way between all the way out or all the way in, Figure 2-42.

The tubing, or pipe, is fastened to these valves by the flare connection or by soldering. The valve is fastened to the compressor by pipe threads or by bolted flanges.

It is good practice to open any valve by first just "cracking" it, i.e., opening it 1/16 to 1/8 turn. This slow opening prevents a shock pressure rush, which may injure mechanisms or flush oil in abnormal amounts.

2-31. SMALL TOOLS

The refrigerating mechanism in comparison to an automobile engine is a relatively light duty one. It can easily be abused. Therefore, when one works on this mechanism, it is necessary to be careful in the use of tools to avoid injuring the unit.

Practically all the common small tools are used on refrigerating units. Such tools as brushes, chisels, hacksaws, hammers, mallets, punches, rules, stamps, vises, etc. are all used in practically every hand tool industry.

2-32. BRUSHES

Work must be kept very clean to obtain good results. Brushes are probably the most satisfactory cleaning tools.

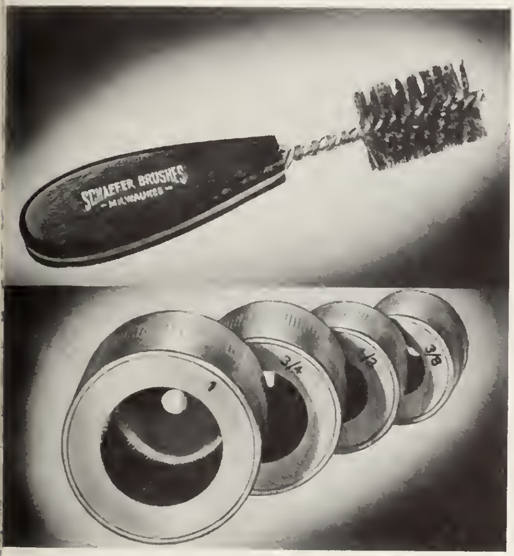
For cleaning copper and steel surfaces for welding or brazing, a clean steel wire brush is the most satisfactory tool. These brushes may be obtained in a variety of shapes and sizes. The brush should have fine steel wire bristles, thickly set, and should have a comfortable handle. Special cylindrical brushes are available in all sizes for cleaning the external and internal surfaces of tubing and fittings prior to soldering and brazing. Figure 2-43 illustrates some good brushes for this work.

Paint brushes are needed to apply paints or to use with cleaning solvents. If used for painting, the brushes should be of the best quality (long bristles). The brushes must be thoroughly cleaned after being used, and they should be wrapped in wax paper and labeled before storing. When used with cleaning solvents, the brush handle should be drilled and the brush hung over the cleaning tank.

File brushes and file cards are very necessary as the file teeth quickly become filled with metal, and unless the clogging material is removed, the files are useless. Do not use the file card for any other purpose as the bristles may become clogged with foreign matter.

2-33. COLD CHISELS

In general, a cold chisel is not needed in a refrigeration shop; but occasionally for odd jobs in the shop, the tool will be found quite useful. Frequently, one will find the assembly devices on cooling coils very corroded, and a chisel will be needed to remove the nut or screw. A 3/4 in. flat cold chisel is the most popular size. Be sure to keep the hammering end of the chisel



2-43. External and internal tubing brushes. (Schaefer Brush Mfg. Co.)

free from mushrooming. Pieces may fly from a mushroomed head causing injuries.

2-34. FILES

For thorough cleaning of metal surfaces and some filing work, files of various sizes and types are necessary.

Files are classified according to their tooth size, their shape, and the number of directions the teeth are cut on the file.

All files are either single cut or double cut, Figure 2-44.

The single cut file is used for finishing surfaces, while the double cut files are used for fast metal removal.

Files come in different lengths: 4, 6, 8, 10, 12 in., etc.; and the coarseness of the teeth is proportional to the length. The size of the teeth on files varies from dead smooth, smooth, second cut, bastard, to coarse. A second cut 6 in. file has much smaller teeth than a second cut 12 in. file.

Files come in a variety of shapes: rectangular, half round, round, triangular, square, wedge shape, etc.

One oddity in files is that there are three types of rectangular cross section files; (1) hand, (2) flat, and (3) mill.

The mill file has only single cut teeth. The hand and flat files have double cut teeth. But the hand file has one edge that has no teeth (called a safe edge) and the edges of the file are straight edges. The flat file has teeth on all four surfaces and edges which are curved.

It is important to use file handles on files to avoid injury.

2-35. HACKSAWS

A hand hack-saw is a popular tool for cutting tubing and for other installation and maintenance work.

2-44. An illustration which shows the difference between a single-cut and double-cut hand file. (Nicholson File Co.)

A rigid frame using a 10 in. blade is the most popular type for this work.

Figure 2-45 illustrates a suitable saw. The blades have different numbers of teeth per inch. Fourteen teeth per inch blades are used for soft metal and wide cuts; eighteen teeth per inch blades are used for medium soft metals; twenty-four teeth per inch blades are used for general work; and thirty-two teeth per inch blades are used for thin metal, tubing, and/or hard metal. One should stroke a hack-saw about 60 strokes per minute and always lift the blade slightly on the back stroke.

With most blades the teeth are hardened while the back of the blade is soft and flexible. The blades are usually tungsten steel alloy, although high quality blades are tungsten, molybdenum steel alloy.

Special hack-saw frames are available to enable one to work in small holes. There is also a stub hack-saw blade and adapter drive to fit electric drills.

2-36. HAMMERS

A hammer is necessary for shop maintenance work. A 12 or 16 ounce ball-peen hammer is the most useful size. It is very important that the head be very firmly fastened to the handle and that the handle be in excellent condition. Correct use of a hammer means to grasp the handle about two-thirds of the way along the handle from the head. One should use mostly the elbow muscles rather than the wrist muscles to move the hammer.

2-37. MALLETS

The mallet is frequently needed to drive parts into place or to separate parts without injury to the surfaces. To do this driving, a 1 1/2 lb. to 2 lb. mallet is the most desirable. A raw-hide, rubber, wood, or lead mallet should be used. The wood or raw-hide mallet is preferred.

2-38. PUNCHES

Center punches are required for locating the position to drill. Remember that the center punch mark must be large enough to hold the point of the drill. Center punches are also used to make alignment marks on refrigeration parts before dismantling.

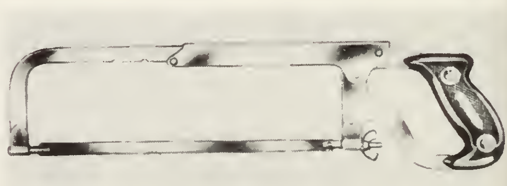
These tools are usually of carefully heat treated chrome alloy steel. The cutting edge must be hard, while the pounding end must be tough and shatter proof. Always grind away any mush-room head that forms. A fairly heavy 6 in. punch will be the most satisfactory.

Drift punches and pin punches are used to remove retainer pins and keys. The blunt end is called the bill. The punches are measured in small lengths and in diameter of the stock. These chrome-vanadium steel punches come in sizes, 3/32 to 5/16.

2-39. PLIERS

Pliers are universal tools. There are many different types for each and every job.

Gas Pliers: These pliers are slip joint combination pliers, and are very handy for general use. They should not be used on nuts, bolts, or fittings, as they might slip and injure the device.



2-45. A hacksaw used to cut copper tubing and pipe. (Duro Metal Products Co.)

Cutting Pliers: These pliers come into good use when working on the wiring of the refrigerator. One type called the lineman's pliers is a powerful cutting and gripping tool. Another type

called diagonal pliers is used to cut in close quarters.

Nut Pliers: A useful tool that is very rapid to use and that saves considerable time when detaching terminal nuts, etc. is a pair of nut pliers. In general, it is considered bad practice to use pliers of any kind on bolts or nuts; but these pliers have parallel jaws and some are equipped with an adjustable cam action that locks the jaws on the device. These are very useful for holding the head of a bolt while turning the nut with a wrench.

Slim nose pliers and duck bill pliers are used to reach into hard to reach places.

Round nose pliers are used to shape wire into loops and to bend sheet metal edges.

Pliers are made of alloy steel, usually with manganese, although some are chrome vanadium steel. All the better pliers are drop forged.

2-40. STAMPS

It is good practice for the refrigeration service man to stamp his name and the date on any unit sold or serviced. This eliminates grounds for arguments. Many companies have a code system whereby only their own employees are able to get the information stamped on the unit. This stamping is done with hardened steel stamps. These may be obtained in a variety of sizes, letters, figures, or symbols. One-eighth inch letters are the most important popular sizes. These stamps should not be used on hardened materials such as tools, etc.

2-41. RULES

A 9 inch or 12 inch steel rule is frequently needed for measuring distances when overhauling units or installing them. The rule should be calibrated in 1/32 inches, and if possible, should be of stainless steel to avoid rusting. The numerals and graduations should be very legible. Installation men will find a 6-foot flexible steel tape of great value when laying out a job.

2-42. SCREW DRIVERS

Screw drivers are extensively used for refrigeration service work; for installation, and for shop work. A complete set of screw drivers will be found highly desirable. The length of a screw driver is measured as the length of the blade, not including the handle. The recommended sizes for the average shop should include 2 1/2, 4, 6 and 8 in. sizes.

There are several types of screw drivers. There is the straight blade or regular screw driver and also a relatively new type of screw driver, the Phillips type, in which a recessed cross in the head of the screw forms a socket for a mating point on the screw driver. Phillips screw drivers are available in four sizes: the 3 in. size for No. 4 and smaller screws, the 4 in. size for No. 5 to No. 9 screws, the 5 in. size for No. 10 to No. 16 screws, and the 8 in. size for No. 18 and larger screws.

The size of the screw end of the screw driver is very important. The screw driver bit should fit the screw slot snugly and the blade should be wide enough to fill the screw slot end to end.

Stubby screw drivers are available for working in small spaces. Screw drivers may be equipped with a screw grasping clip to aid starting a screw. The better quality screw drivers have strong handles firmly bonded to the blade. Plastic handles are very popular.

An offset screw driver is very necessary in refrigeration work as there are many places where it is the only type that can be used.

A hammer should never be used on a screw driver. If a screw driver is needed for heavy service, one with a solid steel handle may be obtained.

2-43. VISES

Sturdy machinist's vises are quite necessary in the shop. The vise is particularly convenient for holding parts during drilling, filing, or assembling.

A pipe vise is also found to be a useful shop tool. Always remember to use soft jaws when working on a part which must not be marred.

It is especially advisable to have a vise large enough to hold most compressor bodies. A vise that is very useful in a large shop installation is a special pipe vise that has a hack saw blade slot for accurately cutting of copper pipe.

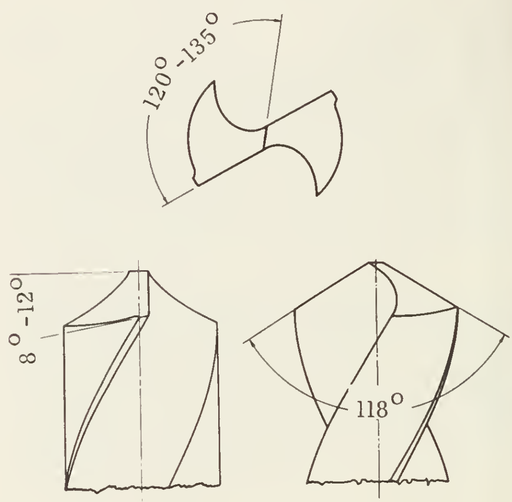
2-46. A typical straight shank twist drill. (Cleveland Twist Drill Co.)

2-44. DRILLS

Drills are frequently used for installation and repair work. Drills are available for drilling metal, wood, plastics, and masonry. These drills are turned by drill presses, hand electric drills and braces. Drills for drilling metal come in three different setsizes; namely, number sizes, letter sizes, and fractional sizes. These drills are usually of the straight shank type, meaning that the drill has a straight round section for gripping by a three jaw chuck. The size and kind of drill is stamped on the shank, Figure 2-46. These drills are either high carbon steel (least expensive) or high speed drills (alloy steel) (H.S.S.). The number sizes 1 to 80 vary in size from .2280 INCH to .0135 INCH. The higher the number, the smaller the drill. Letter size drills are odd diameter drills of over 1/4 inch diameter and vary from .234 for the A drill to .413 for the Z drill. Fractional size drills vary from 1/16 in. to 1 in. by 1/69 of an inch.

Drills are revolved on the basis of cutting speed; the smaller the drill the faster it is turned. Most drills have two cutting edges called lips. These cutting edges must be very sharp, and they must have clearance and a rake angle, Figure 2-47.

Drills are provided with flutes which remove the chips from the hole. Most flutes are spiralled at an angle which automatically provides a rake angle for the cutting edges.



2-47. Correctly ground twist drill. The clearance angle is the angle used for mild steel and cast iron. (The Cleveland Twist Drill Co.)

One must always be sure the drill is cutting when it is used because if the cutting edges are just rubbing against the stock they will quickly heat up and the hardness of the drill will be des-

troyed. To insure that the drill forms the correct sized hole, both cutting lips must be exactly the same length and angle, Figure 2-48. If one lip is longer, the hole being drilled will be oversize; and if one lip has a smaller angle, it will do all the cutting and will soon become dull.

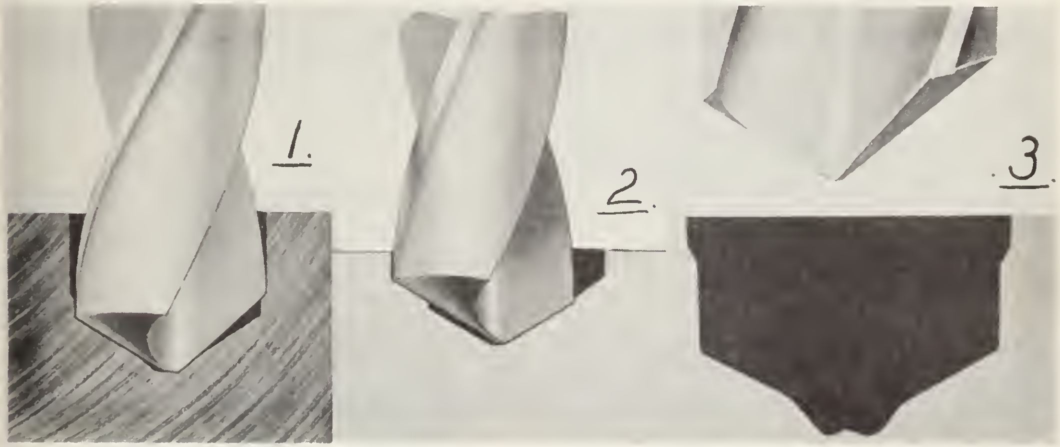
Various devices are used to turn drills. The hand powered drill drives are the hand drills, the breast drill and the automatic or push drill. All of these tools must have a chuck that will hold the drill true. The power drills are the electric hand drill, the breast electric, and the air powered drills.

One should always wear safety goggles when drilling, either in a drill press or with portable drills. All electric drills must be grounded for safety, i.e., the frame of the drill must be electrically connected to a good ground (a water pipe or a conduit).

2-45. FASTENING DEVICES

Many things are made in one piece today that were considered impossible to fabricate a short time ago. However, many mechanisms must still be made of several pieces and then assembled. Also, if there is motion in the mechanism, such as piston in a cylinder, the apparatus must be made of two or more pieces.

Many clever ways have been developed to fasten multiple pieces together. In woodwork pegs, glue, nails, screws, have all been used. In metal work, soldering, brazing, welding, crimping, rivets, bolts, machine screws, pins, spring fasteners, force fits have all been used with success.



2-48. The results obtained when a twist drill is incorrectly sharpened. 1. Lips are equal in length but at different angles. 2. Lips are at equal angles but are of different lengths. 3. Lips are at different angles and are of different lengths.
(Cleveland Twist Drill Co.)

The assembly device that should be used depends first on the kind and the condition of the metal and second on how frequently the pieces must be dismantled.

If the parts are to be put together permanently, riveting, welding, soldering, and brazing are popular assembly devices.

If the parts must be dismantled occasionally, assembly devices are used that can be easily removed without injuring the parts. Nuts and bolts, cap screws, machine screws, and set screws are all used for this purpose. See Figure 2-49.

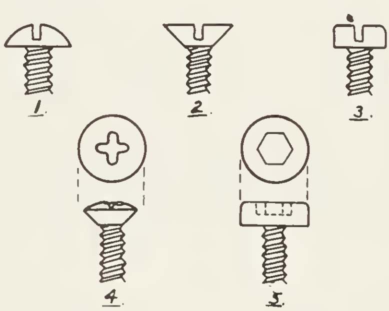
2-46. MACHINE SCREWS

Many small parts are assembled using specially threaded devices called machine screws. These machine screws are made of steel, stainless steel, brass, monel metal, etc. They are available in a variety of head

2-49. Typical nuts, bolts, and cap screws.
(Republic Steel Corp.)

shapes, such as round head, counter sunk or flat head, fillister head, etc. Various methods have been used to turn these screws, such as the regular flat blade screw driver, the allen hex drive, the Phillips cross type screw driver, etc. See Figure 2-50.

These machine screws come in various diameters, eight in the number



2-50. Typical machine screw heads or driving devices. 1. Round head; 2. Countersunk head; 3. Fillister head; 4. Phillips head; 5: Allen head.

sizes, three in the fraction sizes. Each size may have either fine or coarse

Number	Diameter	Threads per in. (coarse)	Threads per in. (fine)
2	.086	56	64
3	.099	48	56
4	.112	40	48
5	.125	40	
6	.138	32	40
8	.164	32	36
10	.190	24	32
12	.216	24	28
1/4	.250	20	28
5/16	.3125	18	24
3/8	.375	16	24

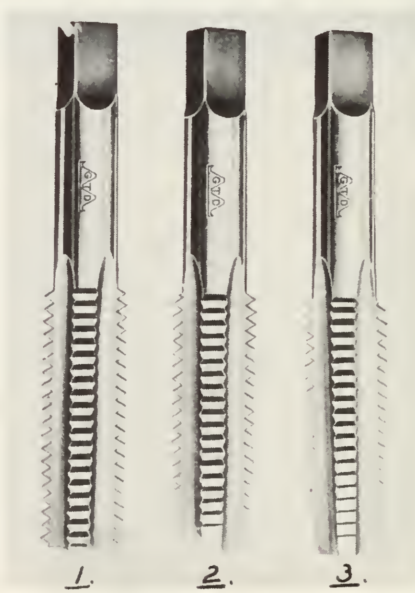
2-51. A table of common machine screw sizes.

threads; the larger the number, the larger the diameter, Figure 2-51.

2-47. TAPS

Many assembly devices require the use of machine screws or cap screws threaded into tapped holes.

For making internal threads in a hole, a tap is used. The taps are made

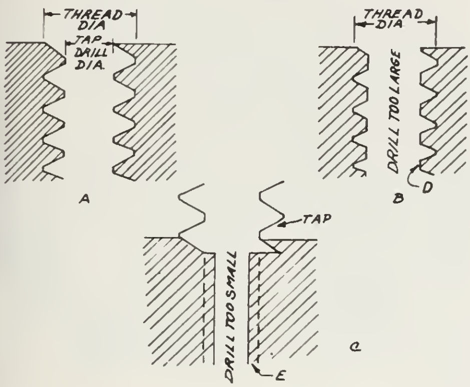


2-52. A set of taps. 1. Bottoming tap; 2. Plug tap; 3. Taper tap.
(Greenfield Tap and Die Corp.)

of hard steel or hard steel alloy,

Figure 2-52. The taps are accurately made with clearance pockets provided for chips; the threads are made with small clearance to provide good cutting.

There are separate taps for each size or diameter thread and also for each kind of thread such as National Fine (NF), National Coarse (NC), or National pipe (NP). Also three types of taps are obtainable for each size. They are the taper tap, the plug tap, and the bottoming tap. The most common tap is the plug type.



2-53. Tapping. A. Correctly formed threads; B. Tap drill too large; C. Tap drill too small; D. Threads are not fully formed. The drill removed too much metal; E. The extra metal to be removed may be the cause of a broken tap.

The shank of the tap is grounded to square shape at the end, and a tap wrench is used to turn the tap. Power tools can also turn taps, but a special tap driving accessory must be used.

Because tapping is basically a cutting operation, all the general rules for cutting metals apply to tapping. Most taps have four cutting edges for each thread. These cutting edges must be sharp. They must have a ground cutting face, and they must have cutting clearance. A coolant and lubricant must be used for tapping most metals.

It is particularly important that the hole being tapped be the correct size, Figure 2-53. If the hole is oversized, the threads will not be full size; and if the hole is undersize, the tap must cut too much metal and will probably break.

Tap	Tap Drill	Tap	Tap Drill
4-36	No. 43	14-20	No. 9
	No. 44		No. 10
	No. 45		No. 11
4-40	3/32	14-24	No. 6
	No. 43		No. 7
	No. 44		No. 8
4-48	No. 41	1/4-20	No. 5
	No. 42		No. 6
5-40	No. 37		13/64
	No. 38		No. 7
	No. 39		No. 8
5-44	No. 36	1/4-28	7/32
	No. 37		No. 3
	No. 38	5/16-18	17/64
6-32	No. 33		G
	No. 34		F
	7/64	5/64-24	J
	No. 36		I
6-40	No. 32	3/8-16	O
	No. 33		5/16
8-32	No. 29	3/8-24	R
8-36	No. 28		Q
	No. 29	7/16-14	3/8
10-24	No. 24		U
	No. 25	7/16-20	25/64
	No. 26		W
10-32	No. 19	1/2-13	27/64
	No. 20	1/2-20	29/64
	No. 21	9/16-12	31/64
	No. 22	9/16-18	33/64
12-24	No. 15	5/8-11	17/32
	No. 16	5/8-18	37/64
	No. 17	3/4-10	21/32
12-28	3/16	3/4-16	11/16
	No. 13		
	No. 14		
	No. 15		

2-54. A table of recommended tap drill sizes. (Greenfield Tap and Die Corp.)

Drill sizes are carefully selected to fit the taps, Figure 2-54. They are called tap drills. If they are correctly used and if the thread on the round stock is correctly cut, the threads will match or contact about 75 per cent which is considered the correct amount for good strength.

Taper taps are used for starting a cut and for tapping thin pieces in which

the tapped hole goes all the way through. Plug taps are used to do most of the cutting in blind holes, while bottoming taps are used to cut full thread to the bottom of a blind drilled hole.

2-48. DIES

Dies are used to cut threads on round stock. They make the external threads that match the threads cut by a tap. Because the tap is non-adjustable, the dies are usually made adjustable to permit careful fitting the threads together. The dies are turned by a die stock which is a special tool to hold the die and turn it, Figure 2-55.

There are dies for each type of thread and each size. Because they are cutting tools just like taps, they too, must be made of tool steel; and they must be carefully shaped to cut the threads correctly.

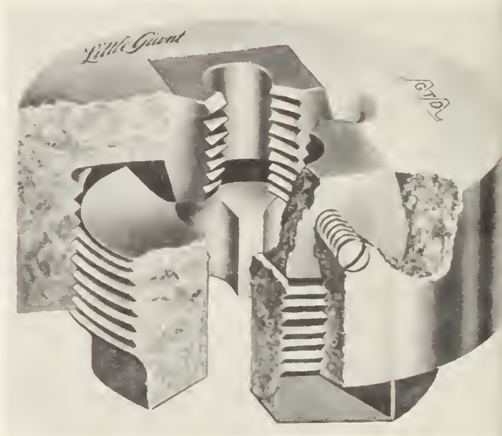
To cut threads straight on a piece of round stock, special precautions should be taken to start the thread

2-55. An adjustable die and die installed in a die stock. (Greenfield Tap and Die Corp.)

correctly. Guides are available that mount in the die stock and closely fit the round stock being threaded. They help cut straight threads, Figure 2-56.

The size of round stock must be accurate. Oversized stock (even if it is only a few thousands of an inch) might break the die. If the stock is undersize, the threads will not be full.

Always use a 1/4 to 1/2 turn and then reverse the turning of the die

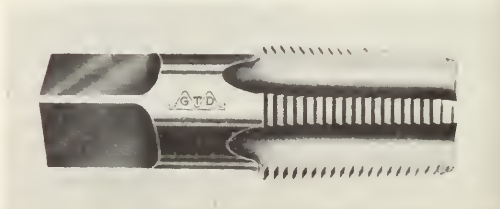


2-56. A threading die with guide. (Greenfield Tap and Die Corp.)

stock when cutting threads both with the tap and the die.

Always adjust the die to full open position. First cut the threads and then adjust the die to cut deeper until the thread just matches the tapped thread.

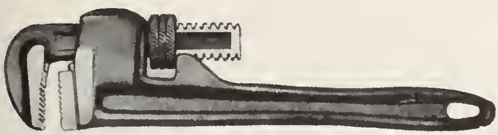
Taps and dies may also be used to clean threads that are corroded or damaged.



2-57. A pipe thread tap. (Greenfield Tap and Die Corp.)

2-49. TAP DRILL SIZES

Before tapping threads in some metal, a correct size hole must be formed in the metal. The most common method is to drill the hole. The drill must be very carefully chosen. If the drill is too large, the threads will not be full size. If the drill is too small,



2-58. A pipe wrench.
(Snap-On Tools Corp.)

the tap will be injured as it attempts to cut too much metal. The tap drill should be just a little larger in diameter than the root diameter of the threads for which it is drilling the hole. Generally speaking, threads 75 per cent of full size are considered satisfactory. Always refer to tap-drill size tables for the correct sized drill.

2-50. PIPE FITTINGS AND SIZES

Air conditioning and refrigeration installations use pipe fittings and pipe threads extensively. Pipe threads (NP) are specially formed V- threads made on a conical spiral that permits the threads to bind against each other when about five (5) threads are threaded into each other, Figure 2-57. If the threads were not tapered, a gasket or a machined shoulder would be necessary to provide a leak proof joint.

Besides being tapered (or in a conical spiral), pipe threads are different from NF and NC threads in size. NF and NC sizes are based on the maximum diameter or outside diameter, whereas pipe thread sizes are based on flow diameter, or the diameter of the hole in the pipe (inside diameter or ID). For example, a 1/4 pipe has close to a 1/4 hole; and when the pipe has a 1/8 in. wall thickness, the O.D. of the pipe will be 1/2 in. (1/8 plus 1/4 hole plus 1/8). The external threads are cut on the pipe with a pipe die which is turned by a standard die stock, a ratchet die stock or power driven die stock. The pipe thread taps (for cutting the female or internal threads) are turned with a tap wrench.

Pipe fittings are made with the threads already tapped. The most common fittings are the coupling, the reducing coupling, the union, the nipple, the 90 elbow, the reducing elbow, the 45 elbow and the street ell.

The threads are made self sealing by the pressing of the sharp V- threads together as they are threaded, Figure 2-58. Various compounds are available to help seal these threads: white lead, red lead, litharge-glycerine mixtures, etc.

A cutting compound should be used when cutting pipe threads. The taps and dies must be kept in excellent condition.

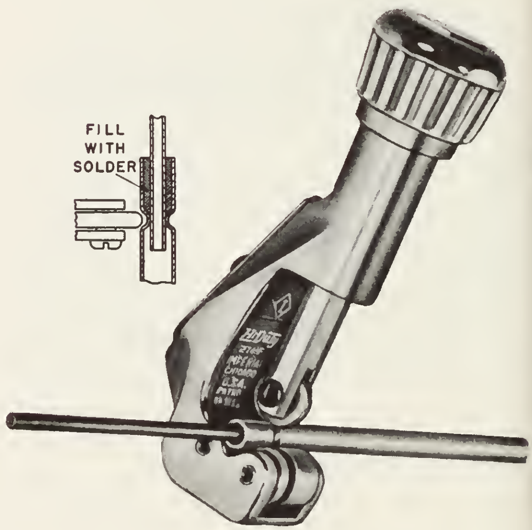
2-59. An assortment of hand tools.
(Snap-On Tools Corp.)

2-51. REVIEW QUESTIONS

1. List the fittings to be used when connecting a compound gauge with 1/8 in. pipe male thread to a service valve having 1/4 in. pipe female thread.
2. When cutting tubing with a hack-saw, what two precautions must be taken?
3. What are the S.A.E. thread specifications of 1/4, 3/8 and 1/2 in. tube flare nuts?
4. What is the thickness of refrigeration tubing? What is the inside diameter of 1/4 in. tubing?
5. What causes copper tubing to harden?
6. Why do some service men file the end of copper tubing?
7. How may an external bending spring be easily removed from the tubing after bending?
8. Is it sufficient to clean metal for soldering with flux? Why?
9. When soldering, how hot must the metal being soldered be?
10. Why must a soldered joint be cleaned after soldering?
11. How may one tell when the correct silver brazing temperature is reached?
12. What is the preferred type wrench to use?
13. Should one push or pull a wrench?
14. How may a 45 degree flare surface be repaired?
15. Describe an easy way to check the accuracy of a thermometer.
16. What is the purpose of a compound gauge?
17. Why must refrigerant oil be practically wax free?
18. What is a very important precaution one must taken when filling cylinders?
19. What is a double cut file?
20. Name the tools in Figure 2-59.

2-52. TUBE CONSTRICTOR

There are many cases where a serviceman needs to make a soldered or brazed joint between two tubes, one tube which fits rather loosely inside the other. Good practice demands that the tubes be as close as .003 in. to



2-60. A combination tube cutter and constrictor. This tool cuts tubing and also enables an oversize tube to be constricted until it very closely fits the inner tube. This process enables quick and high quality soldered or silver brazed joints.
(Imperial Brass Mfg. Co.)

each other. Fig. 2-60 shows a special tool used to constrict the outer tube until it fits the O.D. of the inner tube. Using this tool the serviceman can easily solder or braze the joint without danger of flux getting into the system or leaks.

Chapter 3

COMPRESSION SYSTEM

3-1. LAWS OF REFRIGERATION

All refrigerating mechanisms are designed and built around several basic thermal laws:

1. Fluids absorb heat while changing from a liquid state to a gaseous state and give up heat in changing from a gas to a liquid.
2. The temperature at which a change of state occurs is constant during the change, but this temperature will vary directly with the pressure.
3. Heat will flow only from a body at a certain temperature to a body at a lower temperature.
4. In selecting metallic parts of the cooling and condensing units, metals are selected which have a high heat conductivity.
5. Heat energy and other forms of energy are mutually convertible.

3-2. THE COMPRESSION CYCLE

All compression systems of refrigeration operate on a refrigerant sealed in an air-tight and leak-proof mechanism. This means that in working they repeat over and over the freezing and cooling operations. The process of repetition of a similar order of things is called a cycle. Therefore, all our refrigerators operate on what is called a cycle, meaning a course of events which repeat in the same order.

In mechanical refrigeration two different cycles have been developed. One cycle uses a mechanical compressor to compress the gases. The other type is called the absorption type and works on the principle of temperature and pressure changes resulting from heat applications. The operation of this system is explained in Chapter 13.

The compression cycle is called by that name because it is the compressor which enables a transfer of heat energy. It is by means of the compressor that the refrigerant is able to absorb heat in one place and release it in another. The compressor is that part of the mechanism used to put the heat-laden refrigerant in such a condition that it may dissipate the heat energy it absorbed when it was evaporating at low pressure. Because the compression machine essentially transfers heat from one place to another it may also be called a heat engine or a heat pump.

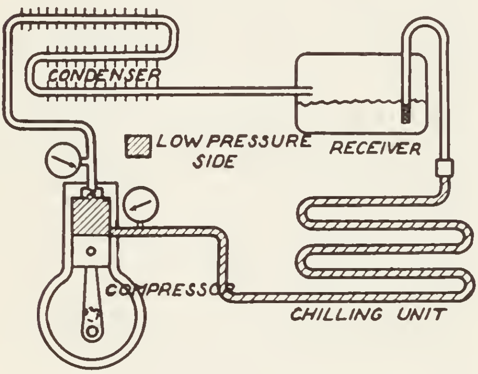
The fundamental cycle for a refrigerating apparatus consists principally of a high pressure side and a low pressure side, Figure 3-1.

The operation of the apparatus is to transfer heat from a certain place to another place, i. e., from the inside of a refrigerator to the outside air, and from the water of a water cooler to the outside air. It may be compared to a sponge picking up water in one place and releasing it in another by pressing it. To have a transfer of heat there must be a temperature difference and to get the temperature differences there must be a high pressure side

(dissipators) and a low pressure side (absorbers).

3-3. THE OPERATION OF THE COMPRESSION CYCLE

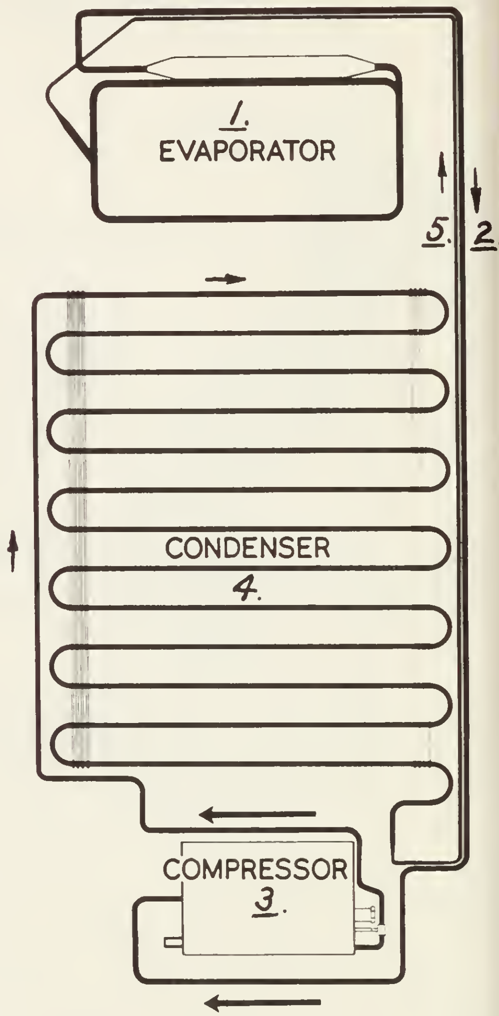
Basically (Figure 3-2), the liquid evaporates in the cooling unit (1) under a low pressure. The pressure will vary in popular refrigerators between 29 inches of vacuum and 13 pounds of pressure depending on the refrigerant used and the low temperature required. This allows the evaporation (absorbing



3-1. A compression cycle showing the two pressure conditions.

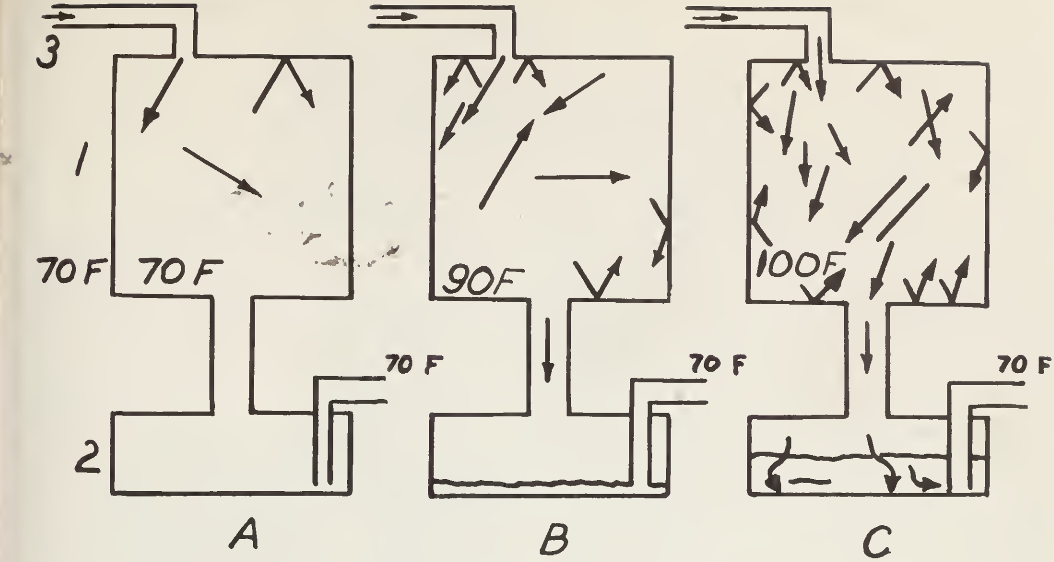
of latent heat) to take place at a low temperature, because, as the pressure decreases, the boiling or evaporating temperature also falls. This heat-laden gas then passes through the suction line (2) to the compressor (3) which compresses and discharges it into the condenser (4) where it cools and gives up its latent heat of evaporation under a high pressure. Then it converts to a liquid and collects in the liquid receiver tank. The liquid line (5) carries the liquid refrigerant to a restriction where the pressure is reduced. The refrigerant then enters the cooling unit where it evaporates and absorbs heat (1) and the suction line (2) carries the gas back to the condensing unit. The following parts are necessary in a refrigeration cycle:

High (Compressor--driven by a motor
(Condenser--heat dissipator



3-2. A compression cycle. (Hotpoint Co.)

High Pressure Side
(Receiver--storage tank
(Liquid line--liquid refrigerant carrier
(Refrigerant control--pressure reducer-restriction



3-3. The behavior of the refrigerant as it changes from a gas to a liquid in a condenser. A. The condition in the condenser as the compressor starts. B. The condition in the condenser after a few minutes of operation of the compressor. C. The condition in the condenser after a state of equilibrium has been reached. The gas is condensing to a liquid at the same rate that it is being pumped into the condenser by the compressor.

Low	(Cooling unit-heat absorber
	(
Pressure	(Motor control-cycling con-
	(trol
	(
Side	(Suction line--gas refriger-
	(ant carrier

The refrigerant control and motor control are used to obtain automatic operation.

3-4. A TYPICAL COMPRESSION CYCLE

The cycle operates as follows: The vapors are compressed in the compressor and passed to the condenser. During compression the pressure increases (due to Boyle's Law), Paragraph 1-17, and the temperature increases (explained by Charles' Law), Paragraph 1-26, until the gas temperature is greater than the temperature of the condenser cooling medium (usually air). Heat will now flow from the condenser to the cooling medium, allowing the gaseous refrigerant to return to the liquid state.

Because pressure is the sum of the molecules bombarding, and because temperature is the speed of molecular motion, it is necessary to speed up the molecules to raise their temperature to a level where they can give up their heat to surrounding cooling surfaces (air or water).

When the compressor first starts, it moves molecules from the low pressure side to the high pressure side without much difficulty and the molecules are not increased very much in speed, Figure 3-3. These molecules are moved into the condenser through opening 3. in A and the temperatures are the same (70 degrees F) inside and out.

As the compressor continues to run, more and more gas molecules are moved into the condenser 1. With each successive stroke, the pressure increases as there are more molecules hitting the sides of the container. The compressor piston pushing the molecules against the higher pressure hits the gas molecules

harder raising their speed (temperature).

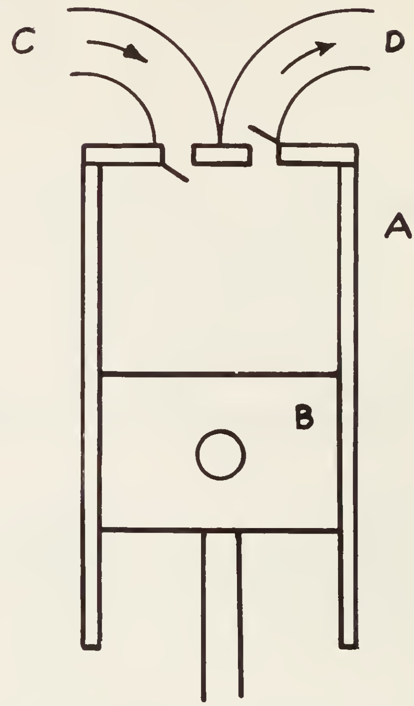
The pressure and temperature continues to rise until the molecules are now traveling at such a high speed that their temperature is higher than the surrounding (ambient temperature). This higher level of temperature causes a flow of heat to the surrounding metal and air. Heat is now being removed from the gaseous refrigerant and this process continues until all of the gas molecules are compressed together and until enough heat is removed to cause some of the gas molecules to become liquid molecules.

(B) The temperature and pressure will continue to rise until a condition is reached whereby as many gas molecules are condensing into a liquid as the compressor can pump into the condenser.

(C) This is a state of balance.

However, if anything should change this balance the condensing pressure and temperature will adjust accordingly. For example, if the room were to get warmer, the heat, pressure and temperature will rise until again just as many gas molecules are condensing as are being pumped into the condenser.

After condensing (liquefying) the liquid refrigerant is stored in the liquid receiver until needed. From the liquid receiver it passes through the high pressure liquid line to the expansion valve (dry system), to the float needle valve (flooded system), or to the capillary tube refrigerant control, where the pressure is reduced to a pressure at which the liquid will evaporate at a temperature of 5 F. to 10 F. In evaporating the liquid in the cooling unit, considerable heat is absorbed and refrigeration furnished. After expansion and evaporation in the evaporator or cooling unit, the gas travels back to the low side of the compressor through the suction line. It passes through the intake valve of the compressor into the cylinder. Here it is compressed and discharged through the exhaust valve into the high pressure side where the heat absorbed in the cooling unit is released. This release of heat causes the refrigerant to recondense and it is then stored in readiness for a repetition of the cycle just described.



3-4. The principle of operation of the reciprocating compressor. A. cylinder; B. piston; C. intake port; D. exhaust port.

3-5. TYPES OF COMPRESSORS

There are several different kinds of compressors:

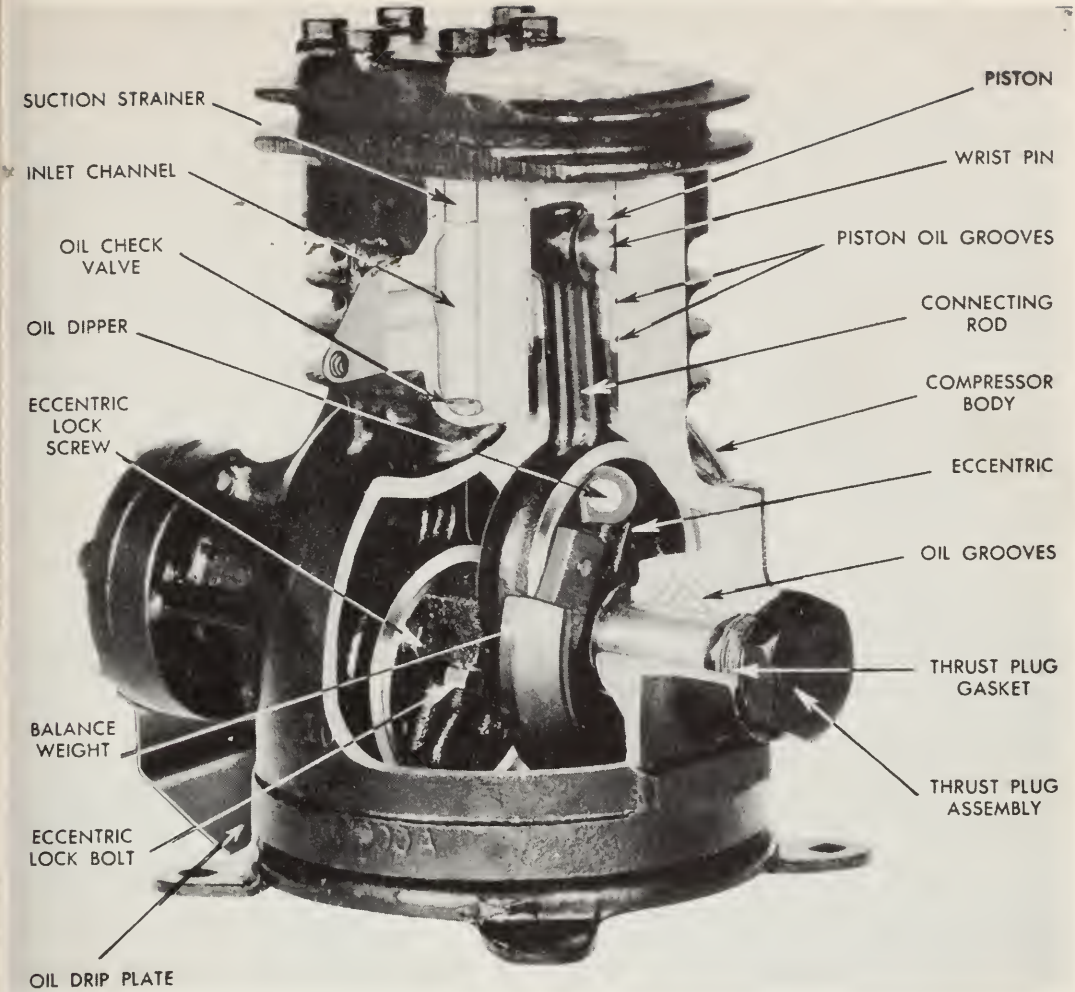
The piston-cylinder type (Reciprocating).

The rotating pump type.

The centrifugal type.

3-6. RECIPROCATING COMPRESSOR

The reciprocating compressor has long been used to pump gases of all



3-5. A modern reciprocating compressor.
(Tecumseh Products Co.)

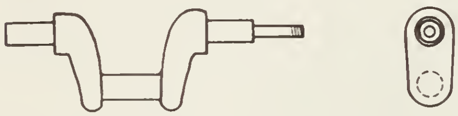
types. It is easy to construct, easy to service and has excellent wearing qualities. Even though its parts can be fitted with practical tolerance, it has a high pumping efficiency.

The compressor basically consists of a cylinder with a piston fitting closely inside. When the piston (B) moves downward, Figure 3-4, a vacuum is produced in the chamber formed and any gas pressure at (C) will rush into the chamber and then when the piston (B) moves upward the gas will be pressed closer together and when its pressure is greater than the pressure at (D) the gas will flow out this opening. Flapper or reed valves prevent the gas from backing up.

The reciprocating or piston type compressor is the most common type in use. Referring to Figure 3-5, it may be seen that this compressor consists of a cylinder, crank shaft, piston, connecting rod, cylinder head, intake and exhaust valves, servicing valves, flywheel, crankshaft seal, gaskets, and oil. It is a very efficient type of compressor. Its construction resembles in many ways that of the automobile engine. The cylinders and cylinder heads are made of a fine grade of cast iron or cast steel and the piston is made

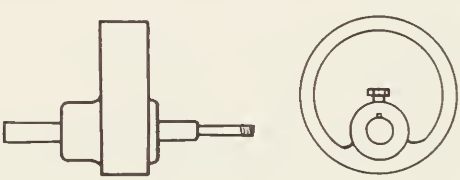
of a similar material. The connecting rods and crank shaft are usually drop forged steel, although some of them are made of cast iron. Bronze connecting rods have been used.

There are several types of crankshafts in use. The most common one is the crank throw type, Figure 3-6. These crank shafts are usually made of steel



3-6. Crank throw-type crankshaft.

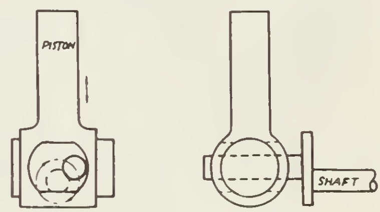
and are case hardened. Some of the compressors use the eccentric type of crank shaft, in which case the eccentrics are made of cast iron as are also the connecting rods, Figure 3-7. An eccentric type crankshaft is permissible in a refrigerating compressor because of the low bearing loads encountered. This eccentric construction reduces the vibration of the compressor when running, inasmuch as the eccentric is a



3-7. An eccentric-type crankshaft.

more balanced type of construction than the crank throw type of crankshaft. These eccentrics are usually made of cast iron and are fastened to the steel crankshaft proper by means of a locking screw. Basically, an eccentric consists of a cast iron disk placed off-center on the crankshaft. Many flywheels are given an unbalance and are so placed on the crankshaft that the flywheel unbalance neutralizes the unbalance of the crankshaft.

In some compressors, the crankshaft and connecting rod is replaced with a scotch yoke mechanism. In this mechanism the piston is not fitted with an articulating connecting rod, but rather this piston extends to the crankshaft and is connected to it by means of a sliding member which attaches to both the piston and the crankshaft, Figure 3-8. This mechanism is used on several of the small high speed direct drive hermetic compressors.



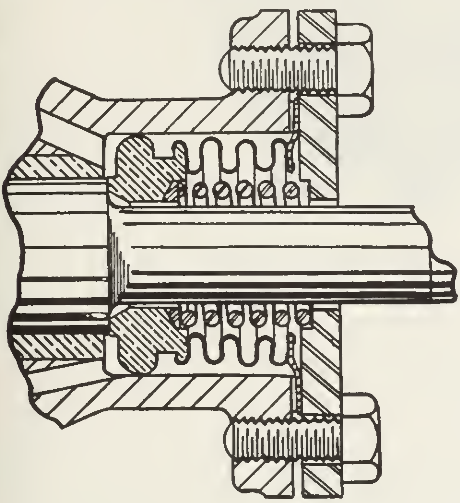
3-8. A scotch yoke mechanism. The crank pin is inserted into one member in the lower end of the piston which slides back and forth as the crank revolves and transfers the rotary motion of the crank into reciprocating motion of the piston.

Where the crankshaft comes through the crankcase to connect to the flywheel, a leak-proof joint or seal must be maintained. This seal must hold under all pressure conditions, and must withstand these pressures whether the crankshaft is stationary or revolving.

The seal consists essentially of a bellows and revolving sealing surface. The bellows consists of a corrugated thin brass tube soldered to a ring of bronze and graphite at one end and to a flange at the other. The flange is fastened to the crankcase with a gasket between the two, while a spring presses the ring mounted on the other end of the bellows against a shoulder on the crankshaft. The two surfaces are perfectly smooth and under the 35-45 pound spring pressure, if lubricated with a little compressor oil, will stand most of the pressures encountered in a

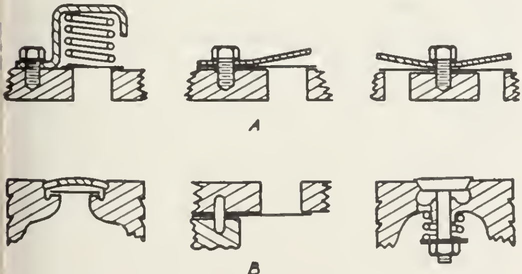
normal system. This seal is called the stationary bellows seal. Seals of this kind have been known to stay in service many years and still give good service, Figure 3-9. Another seal construction attaches the gasket and bellows to the crankshaft. As the crankshaft revolves, the ring on the bellows will rub against a flat, smooth disk mounted on the crankcase.

The compressor valves are usually made of thin steel disks. These disks



3-9. A crankshaft seal.

seat against shoulders constructed into the valve plate. Some designs use springs to keep the valve in place, while others use the pressure differences and the weight of the disk to do this. Figure 3-10.



3-10. Some typical compressor valve designs.

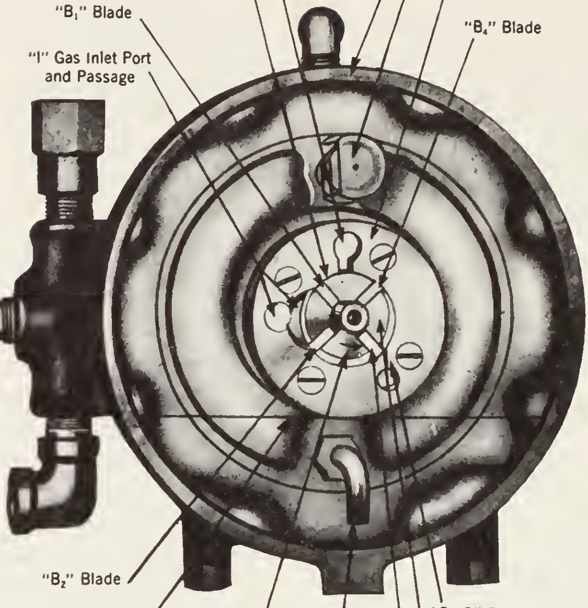
The flywheels are usually made of cast iron with a grooved periphery to fit a V-belt and are often fastened to the crankshaft by means of a tapered shaft, a Woodruff key, and a lock nut. Some flywheels are fabricated from stamped steel parts with the spokes formed into fan blades.

Because the temperatures in a refrigerating unit rarely exceed 175 F., very small clearances may be used between all the moving parts of the unit. Clearances of .0001 in. are very common. This clearance is so little that some manufacturers do not find it necessary to use piston rings on their pistons, as this clearance will not allow the pressures to force much gas past the piston. The purpose of the piston is to compress the gas admitted into the cylinder chamber into the high pressure side. The piston is designed to come as close as possible to the cylinder head without touching it in order to press practically all the gas into the high pressure side. This clearance between the piston and the cylinder head when the piston is at upper dead center is approximately .010 in. to .020 in. The maximum lift allowed the valves without permitting them to become noisy is approximately .010 in. for both the intake and exhaust valves.

The parts are usually bolted together and sealed by means of either paper or lead gaskets. The special paper gaskets must be dehydrated (completely freed from moisture) before use in connection with most refrigerants and must be rubber free. The oil used varies with the refrigerants but dehydrated mineral oil is very good for practically all of them.

3-7. ROTARY COMPRESSOR

Another very popular type of compressor is the rotary type. This has some distinct advantages as far as vibration and moving parts are con-



3-11. A rotary compressor.

cerned. The materials of construction are very similar to those of the reciprocating pump, but its operation is different. Its fundamental purpose is identical, for it takes the low temperature, low pressure gas, and converts it into a high temperature, high pressure gas, but the pumping effect is produced by a rotary motion rather than a reciprocating motion. This pump is illustrated in Figure 3-11. There are two principal types of rotary compressors; one uses sealing blades that rotate with the shaft, and the other has a blade stationary, but the blade has a rubbing contact against the rotating shaft, Figure 3-12.

The operation of the stationary blade type is as follows: The shaft rotates in a chamber so the eccentric on the shaft or the enlargement of the shaft rubs constantly against the outer wall of this chamber. As the rotor turns around in this chamber, the blade imprisons quantities of gas which are compressed into a smaller space, building up the pressure and temperature and finally forcing the gas into the high pressure side of the system.

In the rotating blade type, (Figure 3-11), the low pressure gas is imprisoned between two blades as the blades rub against the wall of the cylinder due to centrifugal force. When the rotor revolves (contra-clockwise in this case) the low pressure gas is gradually compressed into a high temperature, high pressure condition. As the gas, now occupying very little space, comes opposite the opening (D) it passes into the high pressure dome because it cannot go through the point of contact between the rotor and the housing, labeled "X." The small clearance at this point (.0001 in.) plus the presence of lubricating oil makes the

joint pressure tight. The gas cannot back up because of the rotating blade following it. Note that this compressor uses no eccentric, but that the housing is mounted off-center enough to allow the rotor almost to rub against the housing at a point between the intake and exhaust ports.

Rotary compressors occasionally use check valves to prevent the high pressure gas from slowly flowing back into the cooling coil.

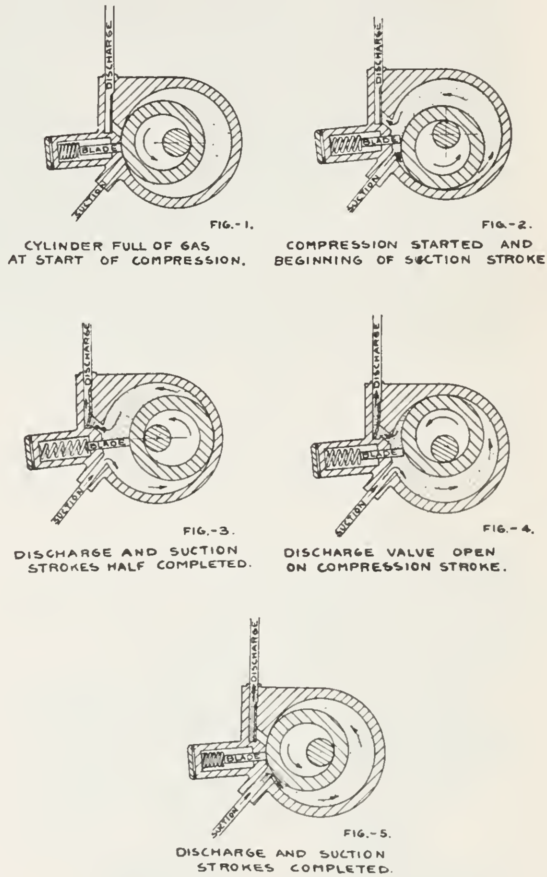
3-8. CENTRIFUGAL COMPRESSOR

The centrifugal type compressor is used extensively in large air conditioning installations. This compressor operates on the principle of increasing the pressure by rapidly revolving circular impellers connected in multiple stages. Several of these impellers are mounted in series in one housing and are usually directly driven by a motor or steam turbine, Figure 3-13. Refrigerants used with this type of compressor possess the ability to function with a low pressure difference between the high pressure and low pressure sides. Refrigerants such as water, methyl formate, Freon F-11, etc., are frequently used in this type of installation.

3-9. MISCELLANEOUS TYPES OF COMPRESSORS

Several ingenious types of refrigeration compressors have been designed and used. The gear compressor is one type that was tried but found to be impractical due to the extremely fine tolerances needed to maintain pumping efficiency. This compressor uses two spin gears, one is driven and it is in mesh with the other. As the gears revolve the gas is carried around the periphery of the gears and then when the gears mesh the gas is forced out of the space between the teeth and out the exhaust.

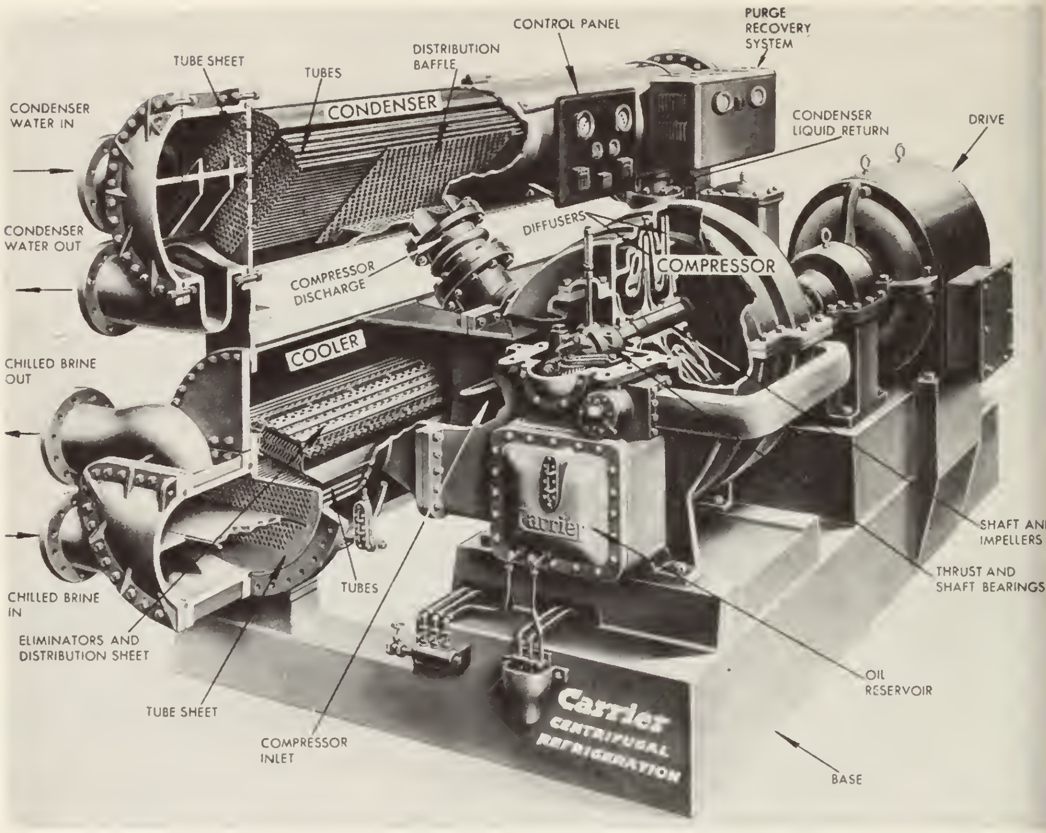
Another type compressor which has not been successful to date because materials have not been found that are durable enough, is the diaphragm type compressor. A crank or a cam pushes a diaphragm, and as it closes in the space gas is forced into the condenser. When the diaphragm is moved out, the space is filled with low pressure gas.



3-12. A stationary blade type rotary compressor. (Norge Sales Corp.)

3-10. THE CONDENSER

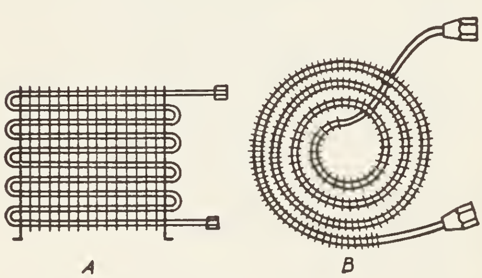
The condenser is usually made of copper or steel tubing upon which fins have been fixed to assist the



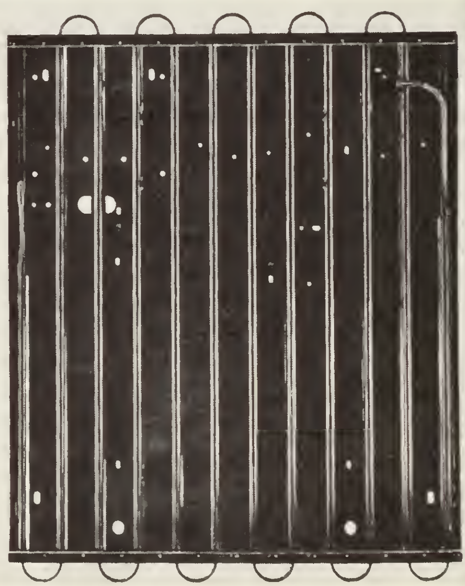
3-13. A centrifugal compressor used in large air conditioning installations. (Carrier Corp.)

rapid radiation of heat, or it may be water-cooled. For domestic use it is usually air-cooled by forcing air over the fins by means of a fan attached to the electric motor, Figure 3-14.

There are several types of condensers in use. The smaller refrigerators use what is called a static con-

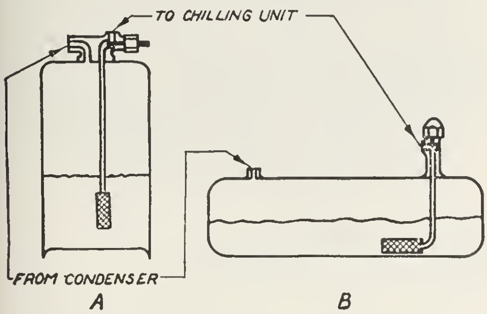


3-14. Two typical air-cooled condensers. A. The flat coil type; B. The spiral type.



3-15. A static condenser (plate). (Houdaile Hershey Co.)

denser. This type consists of two plates of metal with refrigerant passages stamped in them or of tubing with or without fins. The condensers are cooled by air passing over the surfaces by natural convection, Figure 3-15. A firm shroud is usually placed around the condenser to improve the air flow (chimney effect). As the unit size increases, the static condenser becomes too bulky and cumbersome. A forced convection condenser is then used. This condenser uses a fan, a fan motor, finned tubing, and a shroud around the



3-16. Liquid receivers. A. The vertical type; B. The horizontal type.

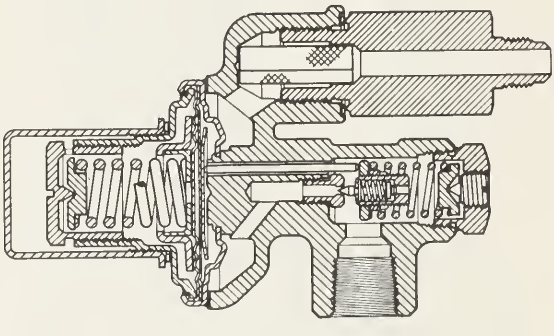
fan and the condenser to improve the air circulation. Although many of the condensers are made of copper, both steel and aluminum tubing have been successfully used. Fins attached to the tubes increase their surface and assist in cooling the condenser. Lint and dust must be removed from condensers regularly or it will interfere with proper cooling.

3-11. THE LIQUID RECEIVER

The liquid receiver is a storage tank installed for servicing purposes and also for taking care of variations in the amount of liquid refrigerant in some systems, Figure 3-16. An excess of refrigerant is always stored in the liquid receiver, and when the mechanism is taken apart the service man usually stores all the refrigerant in the liquid receiver.

These liquid receivers are most commonly made of drawn steel shells welded together. Occasionally one will find a liquid receiver made of a cast material or built into the condenser; that is, the bottom tubes of the condenser form the liquid receiver. Practically all liquid receivers are furnished with service valves by means of which the opening to the liquid line is controlled. A screen of fine copper mesh is usually found in the outlets of these liquid receivers in order to stop any particles of foreign substances from entering the refrigerant control valves.

Liquid receivers are found on practically all systems that use the float controls and the expansion valves. Capillary tube systems, because all the liquid refrigerant is stored in the cooling unit during the off part of the cycle, do not use a liquid receiver. The greater use of hermetic systems and capillary tube refrigerant controls has eliminated much of the need for liquid receivers in domestic systems.



3-17. An expansion valve. (Detroit Controls Corp.)

3-12. EVAPORATOR OR COOLING UNIT

The liquid is now led through the liquid line (high pressure) to the cool-

ing unit where it is reduced to a low evaporating pressure by means of an expansion valve (dry system) Figure 3-17, a float needle valve (flooded system) Figure 3-18, or a capillary tube. This low pressure results in a low boiling or evaporating temperature for the refrigerant with the result that it evaporates and absorbs considerable heat. This heat is obtained from inside the box.

The evaporated refrigerant now passes through the return or low pressure tube (suction line), which is usually larger than the liquid line or high pressure tube, back to the inlet of the compressor.

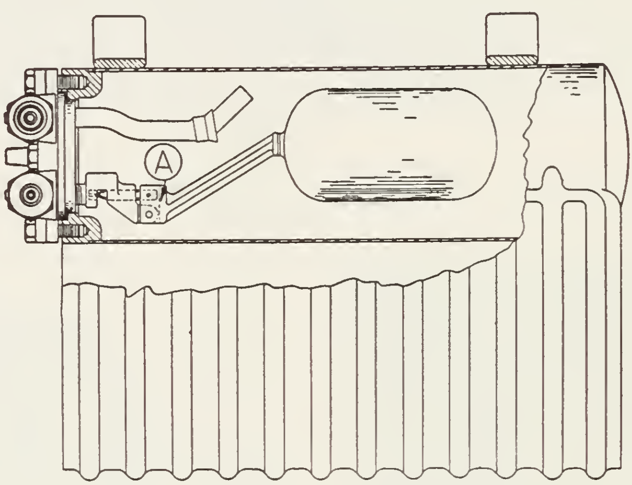
All of the connections, mechanical, soldered, or brazed, must be very carefully made to eliminate any possibility of a leak throughout the entire system.

Cooling units have been made in three different styles depending mainly upon the type of refrigerant control that is used in conjunction with them. There are five principal types of refrigerant controls:

1. Automatic expansion valve.
2. Thermostatic expansion valve.
3. Capillary tube.
4. Low side float.
5. High side float.

If an expansion valve is used, the cooling unit consists of a coil of tubing. The thermostatic expansion valve is popular in commercial refrigeration as it can be used in multiple systems, it is adjustable and it takes up very little space.

When a low side float control is used, the cooling unit consists of a tank out of which run very short lengths of tubing. The tank, of course, contains the float mechanism as illustrated in Figure 3-18. Note that the mechanism holding the float, called a header, is bolted to the cooling coil and also that shut-off valves are usually used on these float chambers.



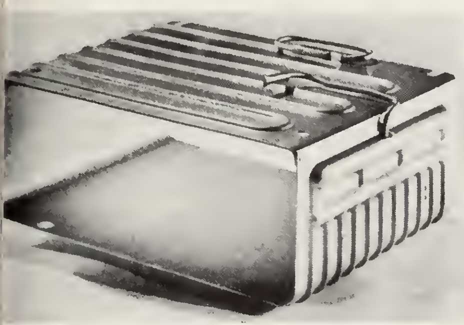
3-18. A low side float refrigerant control and cooling unit.

If it is a high side float or capillary refrigerant control, the cooling unit may be either a cast tank or a series of coils which will provide an evaporating surface for the refrigerant.

Some of the older style cooling coils used a fabricated sheet copper brine tank in which the cooling unit tray holders were constructed. The refrig-

erant flowed through copper coils submerged in the brine. The present tendency is to fabricate these units out of steel shells or aluminum welded together. The steel units are finished with porcelain on the outer surface. Lead gaskets are usually used wherever a joint needs to be sealed.

A recent development in cooling coils has brought forward the shell



3-19. A shell type cooling coil.
(Houdaille-Hershey Co.)

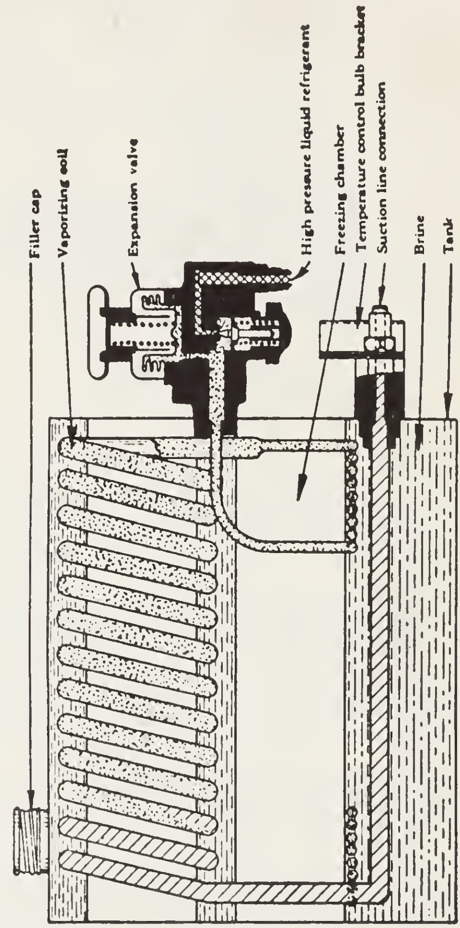
type aluminum plate coil. This cooling coil has the refrigerant passages formed as part of the coil in its manufacture, Figure 3-19.

3-13. THE AUTOMATIC EXPANSION VALVE

The dry system previously mentioned is that cycle where the refrigerant when passing from the liquid line to the evaporator is controlled by an expansion valve with a manual adjustment. That is, as the pressure decreases on the low side, the expansion valve opens and more refrigerant escapes into the evaporating coils where it absorbs heat upon evaporating on the low pressure side. The valve maintains a constant pressure in the cooling coil when the system is running. This system operates independently of the amount of refrigerant in the system. Figure 3-20 shows an old type direct expansion system cooling unit.

This type of dry system is slightly more expensive and is used in installations where a saving of space is an important factor.

The expansion valve is, therefore, one of the division points between the high and low pressure sides of the system. See Chapter 5 for a detailed explanation of expansion valves.



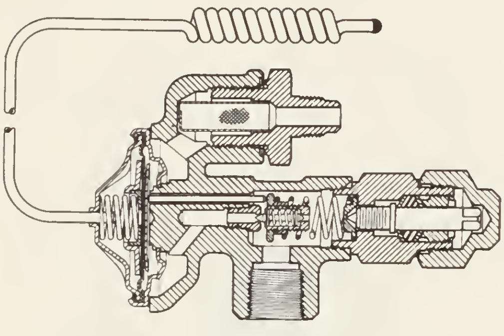
3-20. An old type dry cooling unit using an automatic expansion valve and brine tank.
(Kelvinator Div., American Motors Corp.)

3-14. THE THERMOSTATIC EXPANSION VALVE

Many units, especially commercial ones, are equipped with an improved expansion valve called the thermostatic

expansion valve. This valve has a sensitive bulb located at the outlet of the cooling unit. When this bulb is cooled, the contraction of the fluid in it causes the diaphragm or bellows that it is connected to, to contract, Figure 3-21.

This diaphragm or bellows is connected to the expansion valve needle and

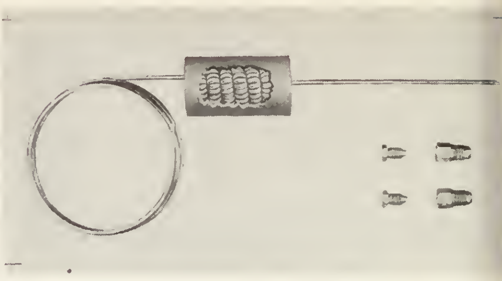


3-21. A thermostatic expansion valve. (Detroit Controls Corp.)

will tend to close it. This addition of a thermo-sensitive mechanism to the valve enables the coil to fill more quickly and permits more efficient cooling. The thermostatic expansion valve operates to keep the cooling coil full of liquid refrigerant when the system is running. See Chapter 5 for a more detailed explanation of its function.

3-15. CAPILLARY TUBE OR CHOKE TUBE

Another method of throttling the high pressure liquid to a low evaporating pressure is to use a long length of small diameter tube. This tube reduces the pressure due to the resistance to flow of refrigerant through the length of the small tubing. The tube is usually about 1/8 in. in diameter outside. It has a variety of inside diameters and is placed between the liquid line and the cooling coil. This inside diameter varies, depending upon the refrigerant, the capacity of the unit, and the length



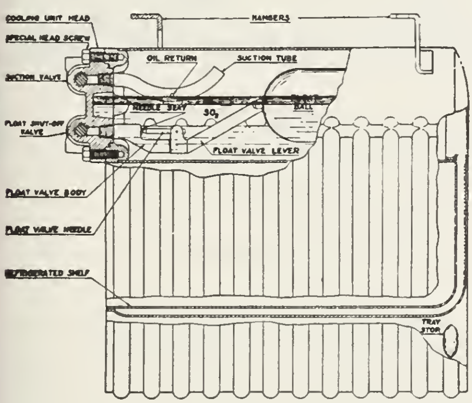
3-22. A capillary tube refrigerant control. (Wabash Corp.)

of the line. The Rice Company was the originator of the capillary tube refrigerant control and built a conventional refrigerator using the capillary tube. An illustration of the capillary tube may be found in Figure 3-22.

The capillary tube operates on the principle of restriction. It operates on the pressure differences between the high pressure side and the low pressure side. A tube is chosen that will allow just enough liquid through it to make up for the amount that is vaporized in the cooling unit as the compressor operates. It thus reduces the liquid refrigerant from its high pressure to the evaporating pressure. Actually there is no change to the liquid except a slight drop in pressure for about the first two-thirds of the length of the capillary tube. Then the liquid starts to change to gas and by the time the refrigerant reaches the end of the tube about 10 to 20 per cent of it has turned to gas. The increased volume of the gas causes most of the pressure drop to occur in the latter end of the tube. Because there is no shut-off valve, the pressures tend to equalize as the liquid refrigerant in the condenser moves into the cooling coil during the off part of the cycle. This equalizing of the pressure permits easier starting of the compressor. It also means that the system must not have an overcharge of refrigerant as the extra refrigerant would tend to fill the cooling unit too full.

3-16. LOW PRESSURE SIDE FLOAT CONTROL (FLOODED)

Another type of refrigeration cycle is the flooded system, which varies only from the dry system in that the evaporating coil is flooded with refrigerant and the amount of the refrigerant is controlled by a float valve. It functions as follows: As heat is absorbed by the refrigerant in the cooling unit, it evaporates and consequently the liquid level falls, which naturally causes a lowering of the float. As the float lowers, it opens the needle valve connected to it, which allows more liquid to enter from the high pressure liquid line taking the place of the evaporated liquid. This makes a very



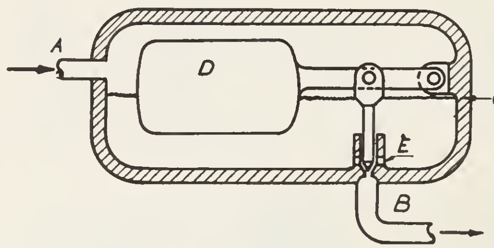
3-23. A low pressure side float.

simple unit with the one disadvantage of needing more refrigerant than the dry system. Figure 3-23 illustrates the exterior appearance of a flooded cooling unit, and the interior construction. The motor control is operated the same is in the direct expansion system type, but uses either a temperature or pressure control switch.

Take particular note of the lever mechanism and the oil layer over the refrigerant. This float control operates by maintaining a constant level of liquid refrigerant on the low pressure side.

3-17. HIGH PRESSURE SIDE FLOAT CONTROL (FLOODED)

This system uses a float located in the liquid receiver tank or in an auxilliary chamber in the high pressure side. It operates as follows: When enough liquefied refrigerant has collected in the float chamber, the float will rise enough to open the needle valve and admit the liquid into the low pressure side or cooling unit. The float



3-24. A high side float refrigerant control. A. Condensed liquid inlet; B. Liquid outlet; C. Liquid level; D. Float; E. Needle and orifice.

controls the level of liquid refrigerant on the high pressure side. The amount of refrigerant in the system must be carefully regulated to allow the cooling unit to have the correct amount of refrigerant and to operate correctly. See Figure 3-24. Any extra refrigerant in the system will be stored in the cooling coil and may over fill it. Any leak of refrigerant will cause a lack of refrigerant in the cooling coil. Chapter 5 describes in detail the high side refrigerant control.

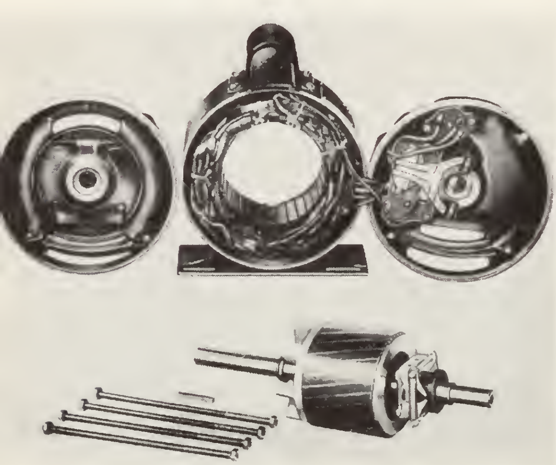
3-18. MOTORS

The driving mechanism or the source of power for these refrigeration units is usually an electric motor. Small gasoline engines have also been used for this purpose. These electric

motors are of a very sturdy construction and are designed to furnish high starting power. To insure quietness, these motors are mounted on rubber or springs, Figure 3-25.

The motors are made in two general types. Open or conventional units use an open motor using a pulley and a belt to drive the compressor through a flywheel. These motors are mounted on a 1/2 or 5/8 in. diameter shaft. The motors usually have bearings that need oiling once or twice a year. They must be carefully mounted to align the pulley with the flywheel and to have the proper belt tightness.

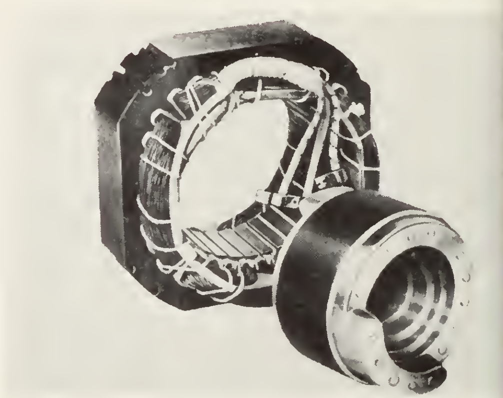
The other type (hermetic) motor drives the compressor directly. These motors are mounted under the same sealing dome as the compressor and are called hermetic motors. These



3-25. An electric motor. This is a rigid mount capacitor motor. The capacitor is in the housing mounted on top of the frame. The centrifugal switch is mounted in the right end and is operated by the centrifugal weights on the rotor.
(The Century Electric Mfg. Co.)

motors usually run at 1750 R.P.M. and are oiled by the same oil as the compressor. Because arcing would deteriorate the oil and the refrigerant, these motors do not use brushes or open points inside the dome, Figure 3-26.

The position of open unit motors is adjustable to facilitate belt adjustment. The size of these motors varies between 1/8 H.P. and 1/3 H.P. for domestic refrigeration, with the 1/8 H.P. and 1/6 H.P. motors predominating. Chapter 7 explains the construction of these motors in greater detail.



3-26. A hermetic electric motor stator and rotor. The rotor is mounted directly on the compressor crankshaft.
(The Emerson Electric Mfg. Co.)

3-19. MOTOR CONTROLS

Practically all automatic electric refrigerators are designed to have excess capacity and, therefore, under normal usage need not run all the time. In the older styles of refrigerators, the compressor would run approximately one hour and then be idle about two hours if the running temperature were normal. Designers have gradually reduced this cycling time until at present, the mechanism runs approximately five to ten minutes and remains idle ten to twenty minutes. The total running time per day remains approximately the same; and under normal running temperature conditions, it is eight to ten hours out of the twenty-four.

There are two principal types of motor controls used to turn the motors

on and off in order to obtain correct refrigeration: Many older units used a pressure type of motor control designed to shut off the electrical power when the low side pressure of the system, corresponding to the temperature desired, indicated that the cabinet was cool enough. It then turned the current on when the pressure had risen to a predetermined pressure corresponding to the allowable temperature rise in the box. This pressure control was used with the low side float systems or multiple systems and was used frequently in commercial systems.

The most popular type of motor control is the thermostatic control which turns the motor off when the cooling unit gets sufficiently cool, and turns it on again when the cooling coil has warmed up 8-10 F., Figure 3-27.

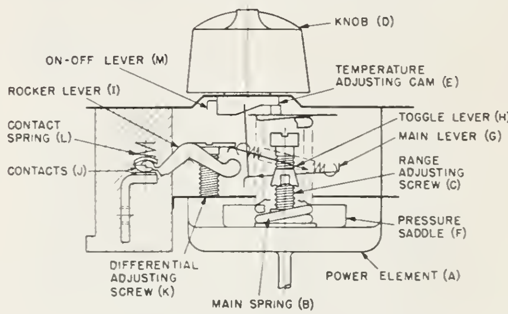
The thermostatic control consists of a bulb connected by a capillary tube to a diaphragm or a bellows. This element is charged with a volatile fluid which will build up pressure when the bulb becomes warmer and will decrease in pressure when the bulb gets cooler.

As the bulb pressure increases, the diaphragm will move out and if the diaphragm is connected to a toggle or snap action switch, it will turn this switch on (close the circuit). Then as the bulb cools and the diaphragm or bellows moves in, the toggle switch will snap open. These controls have adjustments that permit variations in operating temperatures. Many of these controls have a manual switch to permit shutting off or turning on the refrigerator at will. Sometimes they also include an overload protector which will open the switch if the unit draws too much electricity (current). An adjustable knob enables the owner to change the thermostat operating temperatures to meet different operating conditions. These thermostats are also connected to timers and can be used to automatically defrost the cooling coil.

The student should keep in mind the fact that the pressure of the refrigerant in the system varies with the temperature; therefore, temperature may be indicated by pressure. This permits the use of pressures to control temperatures. See Chapter 5 for more details on controls.

3-20. REFRIGERANT LINES

Copper tubing is commonly used to carry the liquid refrigerant from the condenser to the cooling unit and also to carry the refrigerant gas from the cooling unit to the compressor. Tubing made of steel is often used in domestic units. These lines are mounted in back of the refrigerator cabinet or are hidden behind the breaker strip at the refrigerator door jam (frame). The lines are connected by flare connections, or, are fastened by soldering or brazing. It is important that these lines be kept from being pinched or from being buckled. They must also be supported to prevent their wearing or breaking from vibration.



3-27. A temperature motor control.
(Cutler-Hammer Inc.)

3-21. SERVICE VALVES

All units have some means to enable the service man to mount gauges on the system or to check pressures and to put in or take out refrigerant or oil. Some

of the older units had as many as five valves, although three valves are more common. The more recent models use one valve attachment only.

3-22. SUMMARY

There are many compression cycle designs. There must be a compressor, a means to drive this compressor, a condenser, a refrigerant control, a cooling unit, and a means to turn the motor off and on automatically.

3-23. REVIEW QUESTIONS

The answers to these questions will be found in Paragraph 3-24, page 722.

1. How many laws of refrigeration are considered in refrigeration work?
2. Name the eight important parts found in all compression cycle refrigerators.
3. Name the main parts commonly located in the low pressure side.
4. Name the main parts commonly located in the high pressure side.
5. Name four types of compressors.
6. What kind of condensing units do not use a crankshaft seal?
7. Why does a gas rise in temperature as it is being compressed?
8. Why are check valves used in the suction line on some rotary compressors?
9. Why should condensers be cleaned occasionally?
10. What name is applied to the type of cooling coil that uses an expansion valve?
11. What control determines the refrigerator cabinet temperature?
12. Name five types of refrigerant controls.
13. What advantage does an eccentric crankshaft have over a crank throw type?
14. How much clearance is allowed between the piston and the cylinder on small compressors?
15. What is the size of the compression chamber when the piston is at upper dead center?
16. How much lift is allowed the intake and exhaust valves?
17. The low side float maintains a constant ____________ on the low side.
18. The automatic expansion valve maintains a constant ____________ on the low side when the unit is running.
19. The high side float maintains a constant ____________.
20. What is the purpose of the crankshaft seal?
21. Another word for "evaporation" of a liquid is ____________.
22. Of what material are the refrigerant lines made?
23. How does a capillary tube reduce the pressure?
24. When does the condensing pressure stop rising?
25. What basic conditions are necessary to produce refrigeration?

Chapter 4
COMPRESSOR CONSTRUCTION

The heart of the compressor system is the pump or compressor. This pump is the device to raise the termperature of the evaporated gas by compression until its temperature is above the temperature of the cooling medium surrounding the condenser.

It is basically a gas pump and differs from liquid pumps. It is similar in many ways to an air compressor or even a gasoline engine. It must move quantities of gas at the least possible cost. The following paragraphs describe the various compressors that are the result of fifty or more years of engineering development.

4-1. PURPOSE OF COMPRESSOR

A compressor is like a heat engine operating in reverse. It is drawn by an electric motor which supplies the mechanical energy. It compresses the gas molecules until they have reached a sufficiently high temperature so heat begins to flow from these gases into the cooling medium (air or water).

As the compressors continue to operate the surplus rate of flow of compressed gas from the low side to the high side continues until a balance is reached with the rate of condensation of refrigerant on the high side and the high side pressure remains quite constant.

The compressor, a pump, must do this pumping with a minimum of loss in leakage or friction. The compressor must be made durable enough to pump efficiently for thousands of hours of running.

4-2. TYPES OF COMPRESSORS

Many types of compressors have been designed, built and used. However, there are three types successfully used at the present time. These types are:

1. The reciprocating compressor
2. The rotary compressor
3. The centrifugal compressor

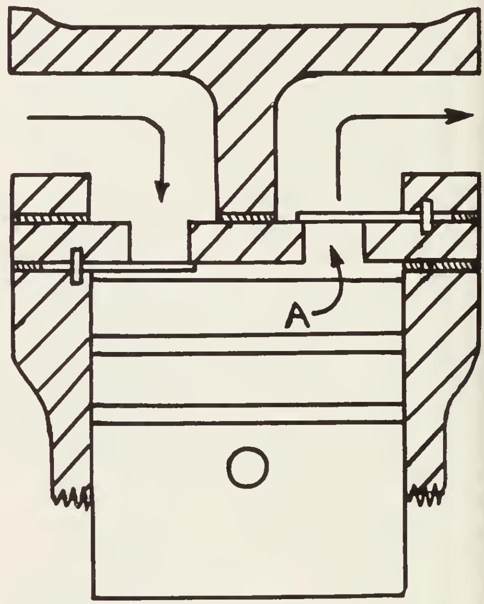
The reciprocating compressor is the most common. Its simplicity of manufacture, its durability and its ease of maintenance make it a very popular choice for a refrigerator pump. The rotary compressor is more compact and can be used with fair efficiency at high speeds, but very close manufacturing tolerances are required. However, millions of these rotary compressors have been built, and they have performed very well. The centrifugal compressor is only used at present in very large sizes.

4-3. COMPRESSOR EFFICIENCY

All of the mechanical energy put into a compressor should be used to move or pump gas. If any of the pumped gas backs through into the compressor on its return or suction stroke, energy is wasted. Likewise, if energy is used

to overcome friction or inertia of the parts, the compressor cannot be 100% efficient. All compressors have frictional losses. If the compressor is run with the inlet valves closed so the compressor does not pump any gas, the power needed to turn the compressor is power needed to overcome friction only. All compressors have frictional losses. The volumetric efficiency of a compressor is the actual volume of gas pumped divided by the calculated volume. It should pump 100% efficiency. If the compressor should pump 10 cu. in. of gas on each revolution or stroke (this is called the piston displacement) but it only pumps 6 cu. in., then the volumetric efficiency of the pump is 60% (6/10).

The volumetric efficiency must be as high as possible. Several factors affect the volumetric efficiency. First, if the head pressure or the pressure the compressor must pump against, increases, the amount pumped per stroke will decrease. Second, if the low side pressure decreases, it is harder for the gases to fill the cylinder, and the amount pumped per stroke will decrease. Third, if the clearance pocket is enlarged, the amount pumped per stroke will decrease. The clearance pocket is the space left in the cylinder when the roller or piston is at the end of its pumping stroke, Figure 4-1.



4-1. The clearance space formed between the head of the piston and the cylinder head. A. indicates the clearance space. Note the valve plate which holds the intake and exhaust valve.

4-4. RECIPROCATING COMPRESSORS

The piston-cylinder type of compressor is known as the reciprocating compressor. To reciprocate means to move to and fro, or back and forth in a straight line. The original compressors were of the reciprocating type. To compress the charge of gas in a reciprocating-type compressor, a plunger or piston is moved into a hollow cylinder or cylinders and the gas is compressed and moved through any opening provided. Then as the piston moves out of the cylinder, a void is created (or partial vacuum). A new charge of gas rushes into this space, and it in turn is compressed and moved into the condenser. Because the original source of pumping energy is usually an electric motor which has rotary motion only, a mechanism must be made to change the rotary motion to reciprocating motion. This change is usually accomplished by means of a crank and a rod connecting the crank to the piston. The complete mechanism is housed in a leak-proof container called a crank case.

There are many types of reciprocating compressors. The most common classification is by the number of cylinders. Most refrigeration compressors are of the single or one cylinder type, but some two cylinder models are in use. They run more smoothly and are more compact. These compressors have also been made in

three, four, five, six, seven cylinder models and even more.

The cylinder arrangement is another method of classifying compressors: vertical single, horizontal single, 45 degree single (inclined), verticle two cylinder, V- type two cylinder. W- type three cylinder, radial three cylinder, vertical four cylinder, V- type four cylinder, etc., have all been manufactured and used.

4-5. CYLINDER CONSTRUCTION

Cylinders of the compressors are usually made of cast iron. The cast iron must be dense enough to prevent the seepage of refrigerant through it. A small amount of nickel is usually added to produce the required density. The castings must be thoroughly aged before machining to prevent any warpage after the finishing operations. The smaller compressors usually have fins cast integral with the cylinders to provide better cooling. The larger compressors have water jackets surrounding the cylinders for cooling. Some compressors are built with a cylinder liner which may be replaced after it has worn.

It is quite common to find part of the crank case as a part of the same casting as the cylinder. This practice minimizes the joints and therefore the possibility of leaks. It also permits very close alignment between the crankshaft main bearings and the cylinder.

The assembly devices that thread into the cylinder usually have national coarse threads due to their greater strength in cast iron.

The cylinder bore in which the piston travels must be made extemely accurate. It is usually made by first boring, and then it is finished by honing and lapping. Some companies then lap the piston and the cylinder together to form a matched set. Some of the smaller cylinders (1 in. in diameter, approximately) have tolerances varying between one ten thousandths (.0001) and one hundred thousandths of an inch (.00001).

4-6. PISTON CONSTRUCTION

The pistons are usually made of cast iron. The pistons are accurately machined and ground on their outer surface to fit the cylinders. The piston must have drilled and reamed holes to fit the piston pin or wrist pin. This pin is the means used to fasten the connecting rod to the piston.

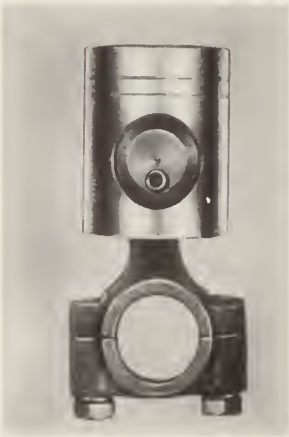
The smaller pistons (1 1/2 or less) have oil grooves around their periphery (outside) of the piston while the larger pistons have grooves machined in them for piston rings.

Because the piston and cylinder temperatures seldom exceed 200 F., all the parts can be fitted together with very little clearance. Approximately .0002 in. should be allowed for each inch diameter of the piston. However, the larger pistons which use piston rings usually are fitted with a little more than this clearance. It is very important to rigidly follow the manufacturer's specifications when one inspects and repairs a compressor.

The piston rings are usually made of cast iron although some bronze rings have been used. The rings are fitted to the groove as closely as possible and still allow movement. A 45 degree tapered or angled ring gap is used to permit the ring to exert a pressure against the cylinder wall. This gap should be approximately .001 for each inch of diameter of the piston.

The piston pins are made of hardened high carbon steel. They are hollow to reduce weight and are accurately ground to be perfectly straight. They are usually the full floating type, which means that the piston pin is free to turn in either the connecting rod bushing or the piston boss bushings. Some

pistons have the intake valve mounted in the top of the piston. This valve construction enables the piston movement to help open and close the valve, but it makes a more costly repair if the valve assembly needs overhaul.



4-2. The assembled piston, piston pin, lock pin and the connecting rod. Note that two cap screws instead of two bolts are used at the crank end of the connecting rod. (General Electric Co.)

4-7. CONNECTING ROD CONSTRUCTION

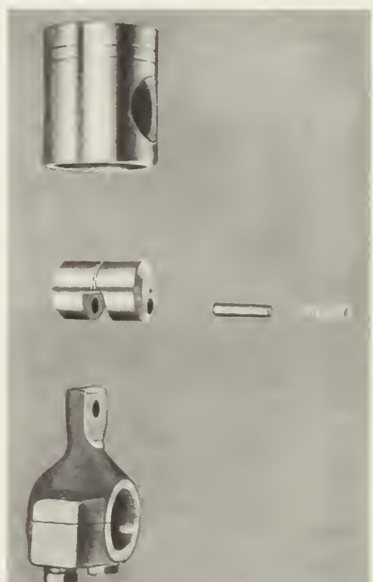
The connecting rod is used to fasten the piston to the crankshaft. The rod is occasionally made of drop forged steel and sometimes of cast iron. The type that is used with the crank throw type crankshaft has a split lower end that clamps around the crankshaft journal. This bearing must be fit to a clearance of approximately .001 inch; it is therefore important that the belts be carefully tightened (torqued).

The eccentric type connecting rod uses its own cast iron as the bearing surface. It is a solid ring and must be mounted on the eccentric before the crankshaft proper is assembled to the eccentric.

A small piston and connecting rod assembly is shown in Figure 4-2. This is used in a hermetic unit. The connecting rod is fastened rigidly to a large piston pin by means of a locking pin and spring. The dismantled unit is shown in Figure 4-3.

4-8. CRANKSHAFT CONSTRUCTION

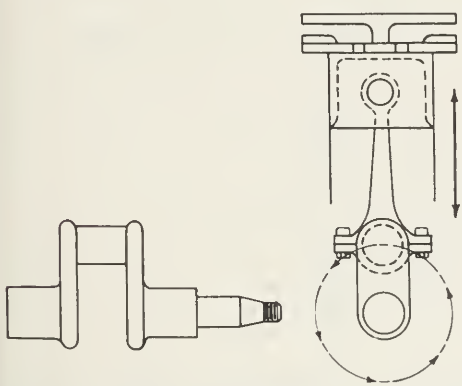
The crank is a rotating lever. It can be used to produce torque on a shaft, or it can be used to change rotary motion to reciprocating motion when used together with a connecting rod, Figure 4-4. This type of crankshaft is usually made of drop forged medium carbon steel or cast steel. The main parts of the crankshaft are the main bearing journals (two or more), the connecting rod bearing journals, the end play bearing or device, the crankshaft seal shaft or shoulder and the flywheel holding device. The wearing surfaces of the crankshaft are usually case hardened. The bearings or



4-3. A connecting rod and piston. This assembly uses a pin to lock the connecting rod to a large piston pin. This design provides an extra large piston bearing area. (General Electric Co.)

bushings that the crankshaft journals turn in are usually made of some

copper alloy (bronze) or lead alloy (babbitt). The accurately ground case hardened journals must fit together with clearances of approximately .001 in. Many of the crankshaft journals are also specially treated (Lubrite by Parker is one) as a safety precaution against bearing failure in case of a temporary shortage of lubricant. It is common practice to fasten the flywheel to the crankshaft with a standard taper, a Woodruff Key and a nut-lock washer combination. One must be very cautious when working on the crankshaft threads that they do not become injured, as this would necessitate replacing the complete crankshaft.



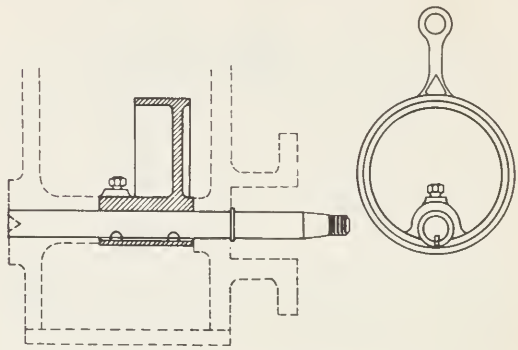
4-4. A crank throw type crankshaft. Note that the crankshaft rotates, the piston reciprocates, the piston pin oscillates and reciprocates, the upper end of the connecting rod oscillates as it reciprocates while the lower end of the connecting rod has a combination reciprocating and rotating motion.

Another type of crankshaft is the eccentric, Figure 4-5. The crankshaft consists of a steel shaft on which is mounted a cast iron eccentric (an off-center mounted disc). This type shaft is less expensive to manufacture; it provides a larger wearing surface for the crankshaft; it is better balanced and is therefore smoother running. The shaft has the two main bearing journals, the crankshaft seal device and the flywheel mounting device. The eccentric is fastened to the shaft by means of a key and a set screw. See Figure 4-6.

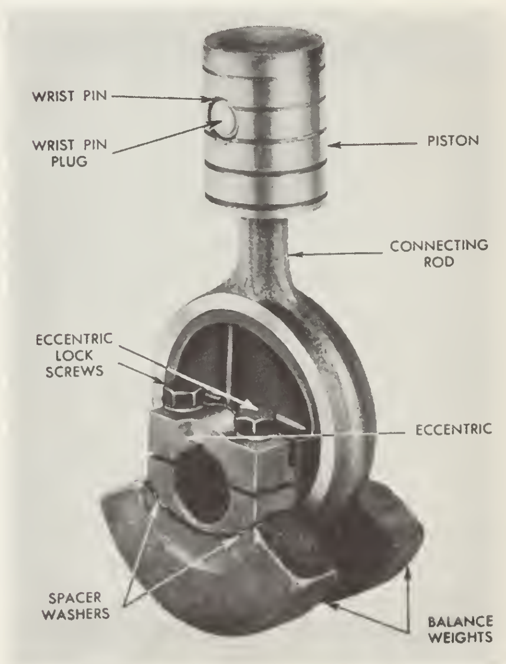
4-9. VALVE CONSTRUCTION

The valve assembly consists of a valve plate, an intake valve, an exhaust valve, and the retainers for the valves, Figure 4-7.

The valve plate is quite commonly made of cast iron although the trend is now toward using hardened steel valve plates as they are thinner and have

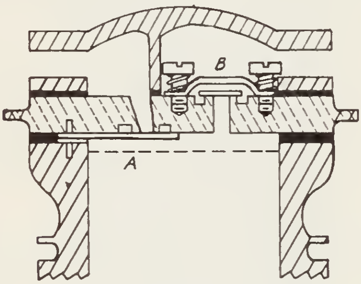


4-5. An eccentric type crankshaft assembly.



4-6. A popular type of compressor piston, connecting rod and eccentric assembly. (Tecumseh Products Co.)

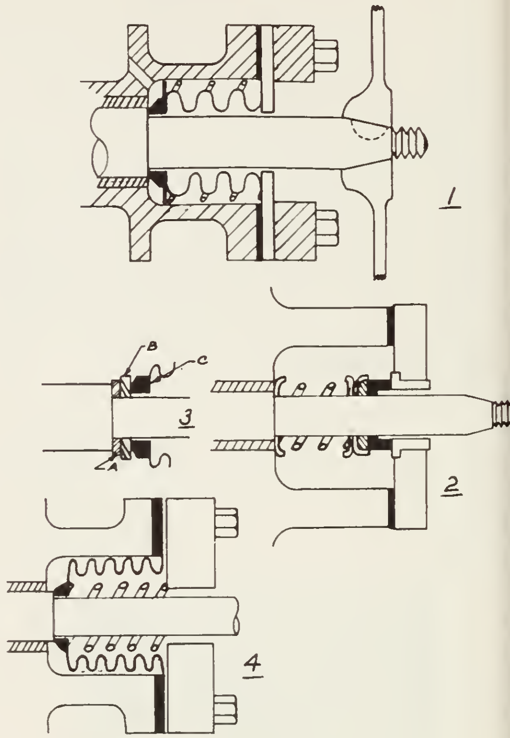
longer wearing valve seats. The valves proper are usually made of spring steel (reeds) accurately ground. The intake valve is usually retained in place by small pins and the clamping action between the compressor head and valve plate. The exhaust valve is also clamped in the same manner, but some of them may be held in place by small machine screws with a spring and a cage. This latter mechanism permits a wider valve opening for those instances when the compressor pumps oil.



4-7. A valve plate design. A. Intake valve. B. Exhaust valve. Heavy springs on the exhaust valve cage allow for possible oil pumping without damage.

The valve discs or reeds must be perfectly flat, differences of only .0001 in. or .0002 in. will cause valves to leak. There is no practical way to repair the discs or reeds so they must be replaced if leaking. The valve seat can be repaired by first grinding the plate on a surface grinder or on a surface plate by hand, and then lapping the plate with the finest lapping powder obtainable.

Of the two valves, the intake valve ordinarily gives the least trouble as it is constantly lubricated by retained oil in the refrigerant gases and it operates at a relatively cool temperature. The exhaust valve, however, must be fitted with great care as it operates at high temperatures and it must be leak proof against a relatively high pressure difference. Because of the high gas velocities and the high temperatures, there is a tendency for the heavy ends of the hydrecarbon oils to settle on the valve and valve seat as carbon. Moisture tends to accelerate the deposit.



4-8. Crank shaft seal designs. 1. Shows external spring bellows type seal. 2. Shows a synthetic rubber (non-bellows) type seal; 3. A replacement crankshaft seal solder. A. Synthetic rubber washer; B. Hardened and ground seal face; C. Soft metal seal ring soldered to bellows; 4. Shows an internal spring bellows type seal.

The valves open approximately .010 in. If their movement is more than this amount, a valve noise develops. If the movement is too little, not enough gas can enter the cylinder in case of the intake valve or leave the cylinder in case of the exhaust valve.

4-10. CRANKSHAFT SEAL CONSTRUCTION

The type of refrigerating system that uses an external motor to drive the compressor must have a leakproof joint

at the place where the crankshaft comes out of the crankcase. This joint requires very clever designing as it is a place where the shaft rotates part of the time and is idle part of the time. The joint must also be leakproof as the pressures vary in the crankcase from a vacuum to pressures as high as the condensing pressure in the system.

The original seal was called a stuffing box. It was a copy of the stuffing box used on steam engines. A lead, graphite impregnated rope was wound around the shaft and moved into a cavity in the crankcase; then a compression nut pushed the packing both against the shaft and the housing. Oil or grease lubricated the joint. Wear on the shaft was natural, and replacement of the crankshaft was a periodic operation.

The metallic seal was developed about 1918. It has replaced the stuffing box completely in refrigeration. There are several types of metallic crankshaft seals. See Figure 4-8. The type that uses the rubber seal rings was not developed until an oil proof synthetic rubber was developed in the late 1920's.

The contact surfaces (the rubbing surfaces) are usually made with one face hardened tool steel and the other of some bearing metal such as bronze. The surfaces must be as straight and as smooth as it is possible to make them. At present they are honed and lapped. They are inspected optically to flatness accuracies of nearly .000001 in. in tolerance.

For long satisfactory service, the seal should be constantly lubricated.

The spring loading of the seal must be carefully calculated. Too much spring force will cause too rapid wear. If the spring force is not enough, excessive crankcase pressures may force the seal ring from the shoulder and cause at least a temporary leak.

The corrugated brass cylinder to which the seal ring and the gasket clamp ring are mounted is usually called a bellows. The bellows must be made of a non-crystallizing metal (non-work hardening). Some companies have used a double thickness bellows, while others have used a small coil spring wrapped around the main spring wire to eliminate critical vibration periods in the seal (chattering).

4-11. GASKETS

As the parts of the compressor are assembled, all the joints that lead to the external surface of the compressor must be sealed. Gaskets are used for this purpose. These gaskets must be made of a material that will not react chemically with the oils or refrigerants used in the system. The material must be compressible without being deformed permanently. The material must not change its size as the temperature changes. It must have an expansion rate close to the coefficient of expansion of the compressor parts.

Gaskets made of cork, paper composition, asbestos, lead, rubber and aluminum have been used. The paper composition gasket is the most popular with lead also being a popular material. Aluminum cannot be used with certain refrigerants as it decomposes. The most important gasket is the one between the cylinder and the valve plate. If this gasket is too thick, it will produce too large a clearance pocket and the compressor will lose volumetric efficiency; and if the gasket is too thin, the piston will pound against the valve plate. If the holes in the gasket where the piston and cylinder contact the valve plate are too large, an extra clearance pocket will be formed.

It is always best to use gaskets furnished by the manufacturers. It is especially important that the replacement gaskets be in perfect condition when used on compressors that use water jackets for cooling.

Many gaskets fail because the surfaces they are clamped between are scored, warped or bruised in some manner. Be sure to check all surfaces for trueness and damage. Recondition the surfaces by filing, grinding or lapping if damaged.

4-12. LUBRICATION

Compressors are lubricated either by the splash system or by the pressure (force feed) system.

In the splash system, the crankcase is filled with the correct oil up to the bottom of the main bearings or to the middle of the crankshaft main bearings. In operation each time the crankshaft revolves, the crankthrow or the eccentric will dip into the oil and splash or sling it around the inside of the compressor. Oil gets thrown on the cylinder walls, up on the piston pin bushings and into small cavities from where the oil drains into the main bearings. This is an excellent system for normal use in small compressors. Some compressor connecting rods have little dips or scoops fastened to the lower ends to aid in picking up the oil and slinging it around to the other parts.

Generally speaking, the clearances between the moving parts is less in this type system. Mainly because, not being under pressure, noisy bearings will occur at smaller clearances than in the pressure feed system.

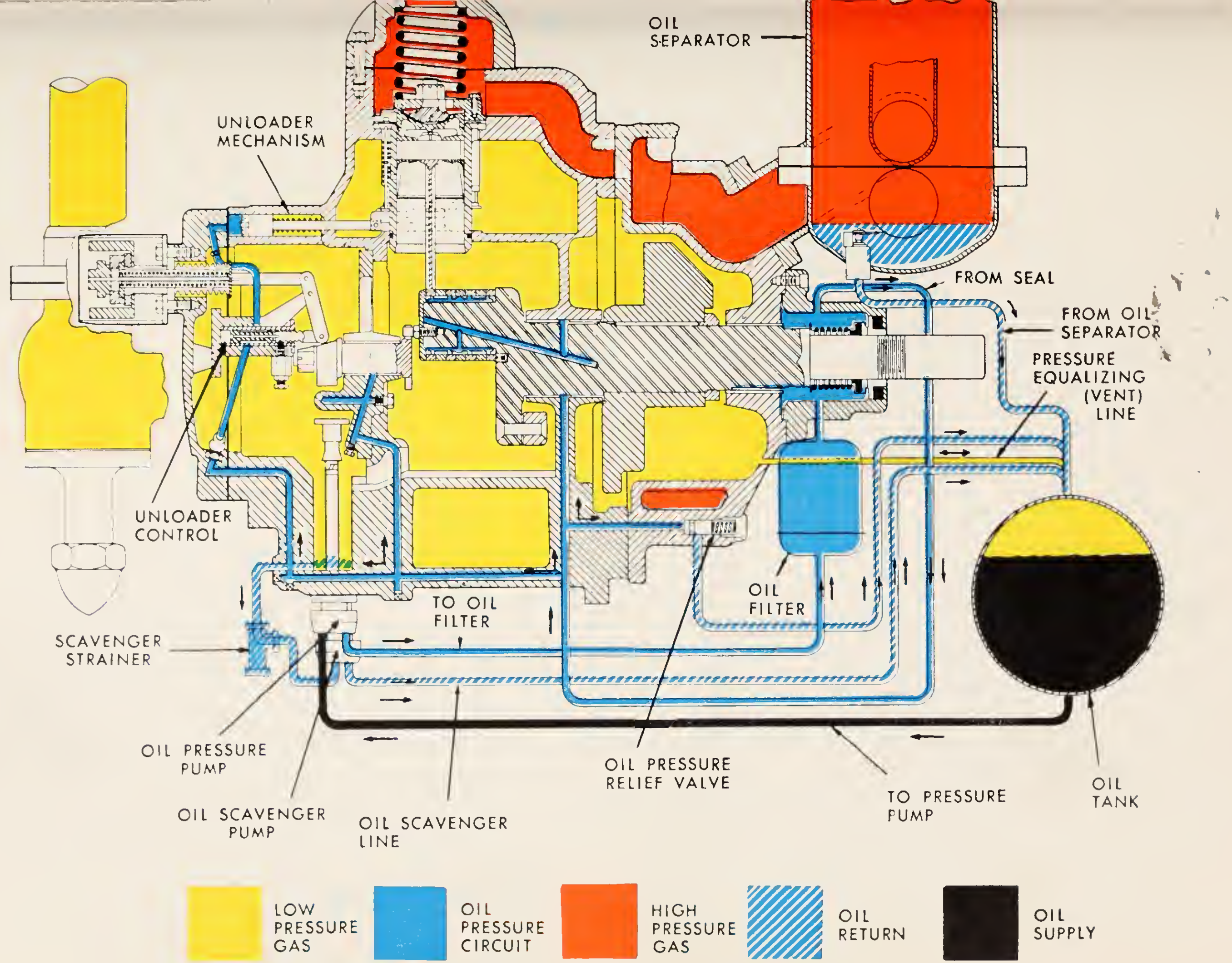
The force feed system is a system which uses a small oil pump to force oil to the main bearings, the lower connecting rod bearings, and, in some cases, the piston pins. This system is more expensive due to the cost of the pump and the cost of drilling the crankshaft and connecting rod. However, the compressor is better protected at all times and it will run more quietly even though there are greater bearing clearances.

The pump is usually mounted on one end of the crankshaft which will be fitted with an eccentric in case a piston pump is used, a gear mounted in case a gear oil pump is used, or a rotor mounted in case a rotor pump is used. Whenever an oil pump is used, an overload relief valve must be built into the pump to protect against excessive oil pressures, Figure 4-9.

4-13. COMPRESSOR DRIVES

Compressors of the external drive type may be driven at a reduced speed or at motor speed. The larger compressors are generally driven at a reduced speed because they are more efficient at the lower speed, and one compressor can be used for several different capacity applications by varying the speed. Bearing, valve, and piston life are increased by using reduced speeds. The reduced speed drive also aids the motor and enables it to start more easily because of the lower starting torque required. The reduction in speed can be produced by using a belt drive, a gear drive or a fluid coupling.

The belt drive is the most popular. V- belts are used in single or multiple. These V- belts have been improved until at the present time they are approximately 98% efficient in power transmission. The slight loss is due to the flexing of the belt as it bends around the flywheel and motor pulley. A big advantage of the V- belt is that it will work efficiently over a large range of tightness. However, the flywheel and pulley must be carefully aligned or excessive end loads will be put on the motor bushings and the compressor bearings. Mis-alignment can be produced by either not having the shafts parallel to each other, or by having the motor pulley ahead or behind the flywheel line.

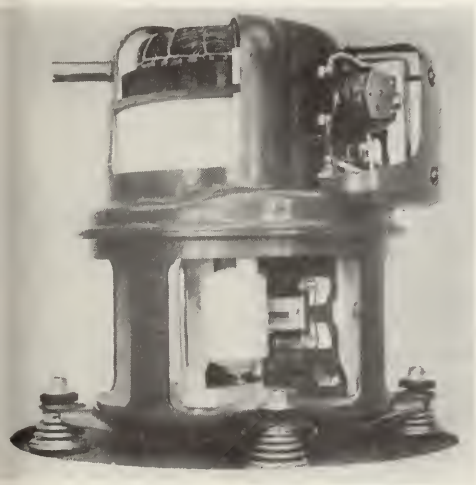


4-9. A pressure feed lubrication system on a multiple cylinder radial compressor. (Airtemp Division, Chrysler Corp.)

Compressor r.p.m. can be determined if one knows the motor speed, the pulley size and the flywheel size.

$$\text{Compressor r.p.m.} = \text{Motor r.p.m.} \times \frac{\text{Pulley diameter}}{\text{flywheel diameter}}$$

A more accurate result is obtained by measuring the pulley diameter and the flywheel diameter from the middle of the V-belt to the middle of the belt on the opposite side of the flywheel or pulley.



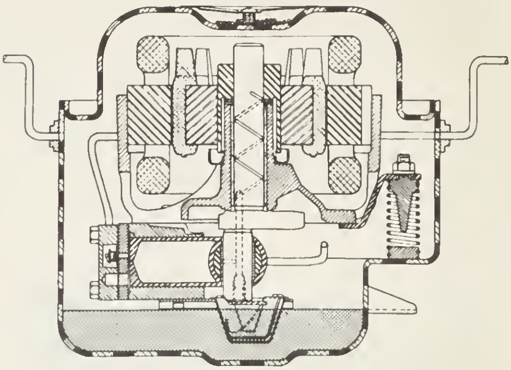
4-10. A reciprocating type hermetic compressor. (Copeland Refrigeration Corp.)

4-14. HERMETIC RECIPROCATING COMPRESSORS

The main difference between the hermetic compressors and the open type compressors is the enclosing of the electric motor in the crankcase or within a sealed housing that also contains the compressor. This construction means that the compressors are directly driven and that they therefore revolve at motor speed. Various cylinder arrangements have been used. One-cylinder models are popular for small units, while two-cylinder units are the most common in the larger units.

The details of the materials of construction and the design of the compressor itself are practically identical to the open compressor, Figure 4-10.

There are three basic hermetic designs. One type encloses the compressor and motor in a steel casing sometimes called a dome or a "hat." The motor stator is sometimes pressed into one half of this dome and the compressor is bolted to this stator. This



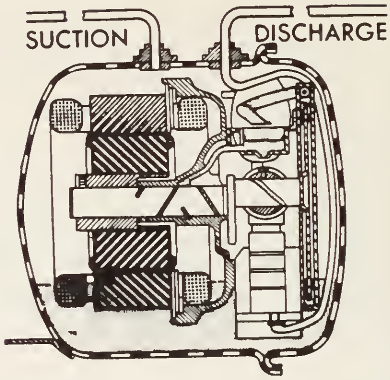
4-11. A hermetic compressor with a scotch yoke drive. Note the internal springs, the hollow piston, and the one main bearing. Crankshaft and play is absorbed by a thrust bearing located at the upper end of the main bearing. (Crosley Div., Avco Corp.)

type is externally mounted on springs or rubber mounts for vibration absorption. Another design has the motor and compressor assembly mounted on springs inside the dome or casing. The casing is usually made in two pieces and the joint is automatically welded, Figure 4-11. The third type uses the compressor body itself as the casing and extends the crankcase of the compressor to hold the motor. This type unit usually uses a bolted assembly and is commonly called a serviceable hermetic because it can easily be dismantled and assembled, Figure 4-12.

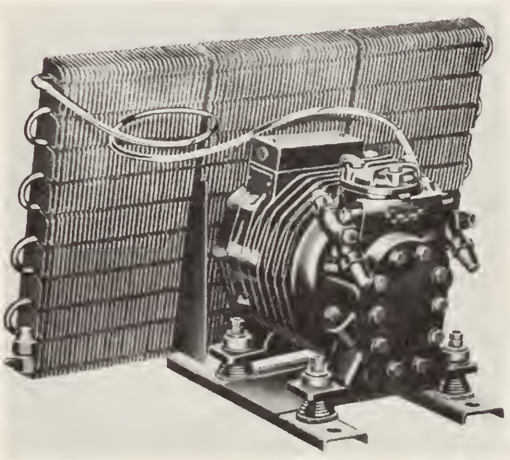
A major engineering problem when designing hermetic units is the proper cooling of the electric motor. One method used to aid cooling the motor is to press the stator into the dome to provide easy heat transfer from the

motor windings to the casing. Another method is to pass the returning gas around the motor windings before it is compressed by the compressor. This relatively cool gas removes much of the heat, but it has a tendency to warm the returning gas enough to reduce the volumetric efficiency of the compressor somewhat, Figure 4-13.

A hermetic motor compressor that revolves at 3600 r.p.m. is shown in Figure 4-14. The two pole motor drives a one-cylinder compressor by means of a scotch yoke. This unit has an intake valve in the piston. A pressure lubrication system is used. The pan on the left has an oil cooler "V" tube attached to it.



4-13. A single cylinder hermetic compressor. The suction gas flows over the motor windings. At the right a disk picks up the oil and carries it up to a reservoir. The oil then feeds by gravity to the crankshaft.
(Crosley Div., Avco Corp.)



4-12. A bolted type hermetic compressor-motor assembly.
(Copeland Refrigeration Corp.)

4-15. MUFFLERS

Most of the smaller hermetic units have sound deadening devices on both the intake and the exhaust openings of the compressors. The mufflers eliminate the sharp gasping sound on the intake stroke and the even sharper puff of the exhaust gases. These mufflers are small brazed cylinders with baffle plates mounted inside and based on Bernoulli's Theorem, the increased volume slows the velocity and reduces the annoying pumping sound, Figure 4-15.

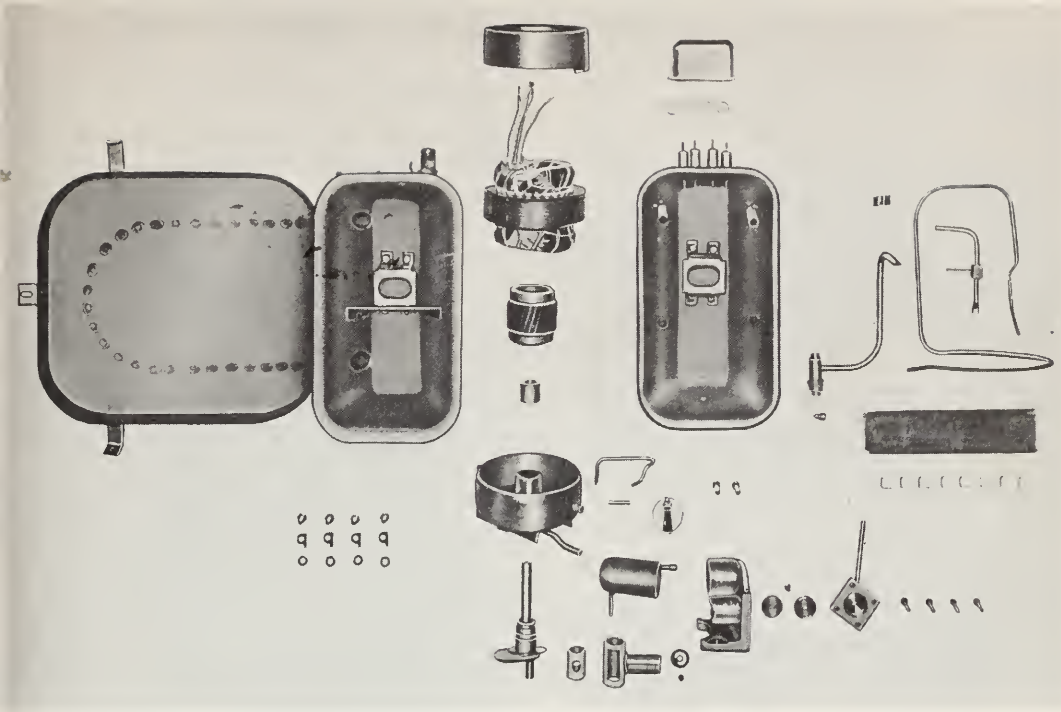
A complete assembly of both the intake muffler and exhaust muffler is shown in Figure 4-16. The outer holes are the intake ports and the inner half ring of holes are the exhaust holes.

4-16. COMPRESSOR COOLING

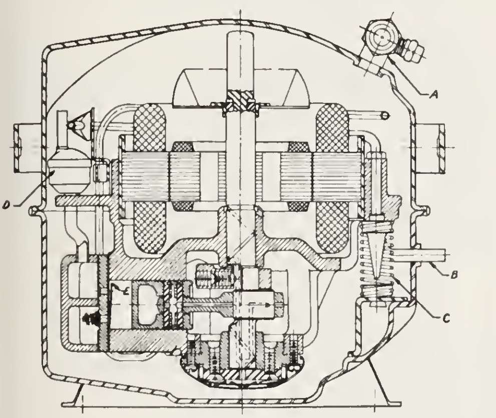
The compressors heat up from the friction between the moving parts. They also heat up because the almost perfect adiabatic compression increases the temperature of the gas which then loses some of its heat to the compressor. This heat must be removed to prevent excessive loss of efficiency of the pump and to reduce the decomposition of the oil.

The oil that circulates in the compressor is an excellent remover of heat. It receives the heat from the friction surfaces and carries this heat to the outer surfaces of the unit.

Air is very commonly used to remove heat from the outer surface of the compressor or the dome. To increase this heat removal, many compressors



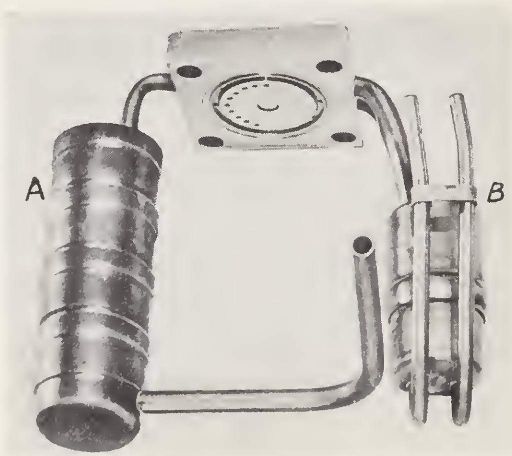
4-14. An exploded view of a 3600 R.P.M. hermetic motor-compressor. The piston and crank are of the scotch yoke design. The four terminals are needed because the motor has three windings.
(General Electric Co.)



4-15. A hermetic motor-compressor unit. A. Suction service valve; B. Discharge gas opening; C. Internal mounting spring; D. Intake muffler; E. Intake valve.
(Tecumseh Products Co.)

and many domes have metal fins on their outer surfaces. Some even use a motor driven fan to force air over the compressor to help remove this heat.

When a water cooled condensor is used, it is found advantageous to also use water to cool the compressor or dome. Cast-in water jackets are used on some open compressors while occasionally copper tubing is wound around the hermetic dome to carry coolant.



4-16. The cylinder head and muffler system. A. Exhaust; B. Intake.
(General Electric Co.)

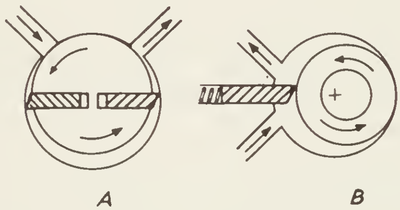
4-17. ROTARY COMPRESSORS

Rotary compressors are very popular in the refrigeration field. They are compact and have very little vibration. Several types of rotary compressors have been built; namely,

1. The stationary blade type
2. The rotary blade type

These two types could also be classified by their cylinder design.

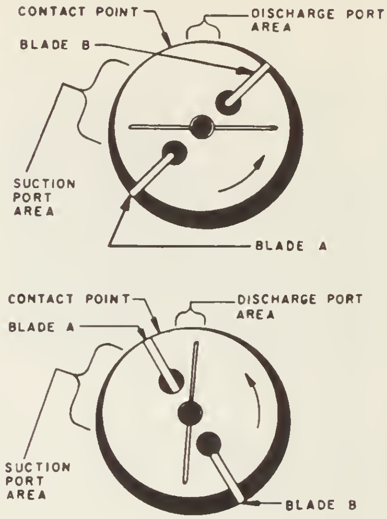
The stationary blade type could be called the concentric cylinder model



4-17. The two principal types of rotary compressors. A. The rotary blade type; B. The stationary blade type.

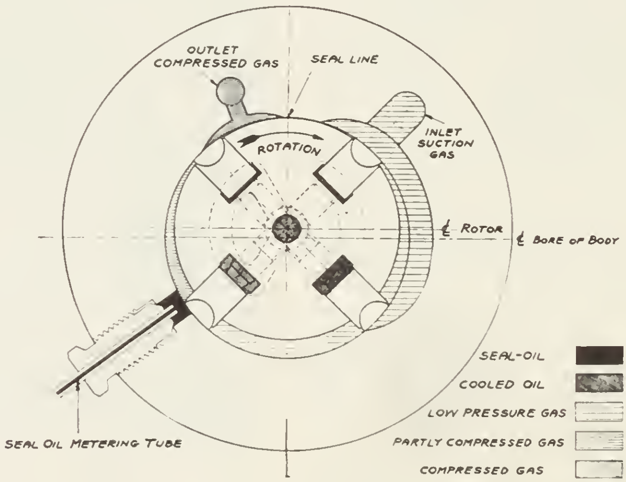
and the rotary blade type could be called the eccentric cylinder model. See Figure 4-17.

The principle of operation of the stationary blade type is that the rotating cylinder is mounted on an eccentric



4-19. A two blade rotary compressor operation. The blade rotor is off center. Blade A is passing through about 90° of its suction motion while Blade B is passing through about 90° of its compression motion. (Seeger Refrigerator Co.)

shaft. This rotating roller is sealed at its ends by plates fastened to the ends of the cylinder. As the roller rotates it leaves a space between it and the under part of the blade and the cylinder. This space is filled with the suction gas from the cooling coil. This filling action continues until the high part of the roller pushes the blade completely



4-18. A four blade rotating blade type compressor.

out of the space back into its slot. Then as the high part of the roller continues past the intake opening or port, this gas charge is trapped in the cylinder cavity. The roller now squeezes this gas into a smaller and smaller space between the upper part of the blade, the cylinder and the roller. As may be noted, the compressor has almost a full revolution for its compression stroke and likewise for its intake stroke. All the parts must be fitted to extremely close tolerances and clearances. Any scores or clearances will allow the gases to pass by the roller surface or roller ends and reduce the efficiency of the pump.

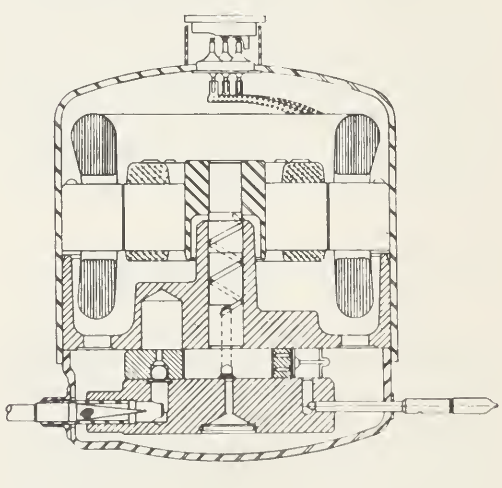
4-20. A hermetic motor-compressor. It uses a split phase motor and a two blade rotary compressor. (Seeger Refrigerator Co.)

The rotating blade type of rotary compressor mounts the cylinder off center from the shaft in such a way that the shaft roller comes to within .00001 in. of the cylinder at a spot between the intake and exhaust ports. The roller usually has two or four slots in which are mounted two or four blades that rub against the inner surface of the cylinder, Figure 4-18. The ends of the blades must fit the length of the cylinder with clearances of approximately .0005 in. For pumping efficiency the blades must also have about this same clearance in their slots. Some compressors use two blades 180 degrees apart, Figure 4-19.

As the roller rotates, a space is formed between the cylinder, the blade, the roller and the point of contact between the roller and the cylinder. This gas charge is trapped into smaller and smaller spaces as the next blade moves past the contact point.

A hermetic unit with a vertical crankshaft and using a two blade rotary compressor is shown in Figure 4-20. The electrical leads are at the top of the unit and it is externally spring mounted. The three bottom connections are, left to right, suction line, discharge line, and the oil-out line. The oil inlet line is at the upper left of the housing. This unit has 1/9 and 1/8 H.P. motors.

The internal construction of this compressor is shown in Figure 4-21. The suction line is at the left and the discharge line is at the right. A conical screen is located at the inlet and a check valve is located in the vertical section of the suction passage.



4-21. The internal construction of a hermetic motor-compressor. The motor stator and rotor are at the top. The rotor is mounted on the eccentric shaft which drives the compressor rotor at the bottom of the shaft. (Seeger Refrigerator Co.)

4-18. CYLINDER CONSTRUCTION

The cylinders are usually made of cast iron. The cylinder is accurately machine-honed, and lapped on the inner surface and on the ends. The cylinder contains the intake and exhaust ports; some models have oil passages for lubrication. This cylinder is usually mounted on an end plate that is part of the main crankcase of the compressor and the refrigerant passages continue into this port. The exhaust valve reed is mounted on the exhaust port outlet of the compressor as close to the compression chamber as possible. Four or more bolts hold the cylinder to the main part of the compressor. There are also one or more steel dowel pins to help align the cylinder on the compressor. After the cylinder is mounted, in the rotating blade type, snugly on the back plate, the cylinder is moved by tapping it slightly until the cylinder binds on the roller. A light tap is then used to relieve the binding and the bolts are now tightened to their proper torque.

In the stationary blade type compressor, the cylinder is mounted snugly, and then the shaft is turned and the cylinder is shifted until there is an equal amount of resistance for the complete revolution. Then the cylinder bolts are tightened (torqued).

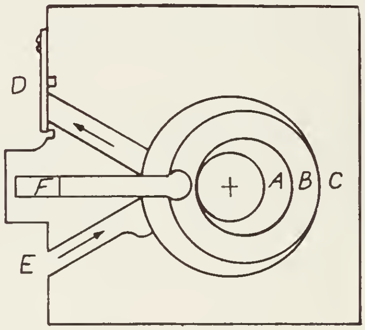
4-19. ROTOR CONSTRUCTION

In the rotating blade type compressor, the rotor is a fixed part of the shaft. Its length must be accurate to .0005 in. It cannot have any scores on its outer surface. Its slots must be free from burrs and they must be true. The blades are lapped to fit the width and length of the slots. Usually the slots are on a radius to the center of the shaft, but one company puts the slots at an angle to prevent the blades touching the cylinder until the compressor has reached almost its operating speed, thus reducing the starting load.

In the stationary blade type of compressor, the rotor is usually a roller that accurately fits the eccentric which is a fixed part of the shaft. Some compressors have the blade fastened to the roller to provide a positive means to move the blade in and out of their slot and to provide a more positive leak proof joint between the roller and the blade. However, this construction puts all of the wear on the eccentric surface and the inner surface of the roller, Figure 4-22.

4-20. BLADE CONSTRUCTION

The rotating blade type compressor usually has two to four blades. These



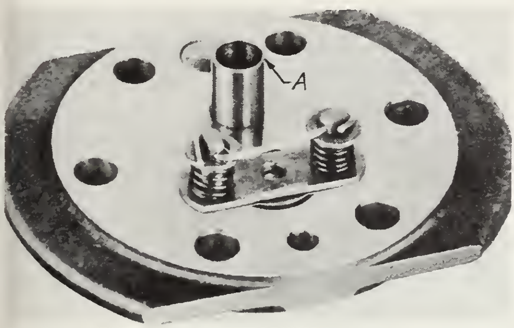
4-22. A stationary blade compressor with the blad attached to a bushing mounted on the revolving eccen tric. A. Eccentric shaft; B. Bushing; C. Cylinder; D Exhaust valve; E. Inlet port; F. Blade.

blades have been made of cast iron steel, aluminum and carbon. One company made the blade in two pieces t enable the blade contact surface on the cylinder to be the full width of the blade at all times. The efficiency of the compressor depends to a great extent or the condition of the contact edge of the blade with the cylinder. Blades must have perfectly smooth edges and their length must be exactly the same as the

cylinders. Aluminum and carbon blades are used to reduce blade clicking noises and to reduce chattering of the blades.

4-21. CRANKSHAFT CONSTRUCTION

The crankshaft is usually of forged steel construction. It is made of medium carbon steel and the high wear surfaces are then case hardened. It usually has two journals for the two main bearings although some have been built with only one main bearing. End play of the shaft is usually absorbed by a shoulder on one main bearing journal and by using the seal spring as an initial load device.



4-23. A valve plate assembly. The opening to the inlet valve (A) is raised above the valve surface to avoid oil pumping. The exhaust valve retainer is spring loaded to allow for possible oil pumping without damaging the compressor mechanism.
(Tecumseh Products Co.)

The shaft also has the taper shoulder, a woodruff key slot, and the threads for the flywheel and retaining nut. It is important that the main bearing journals be straight and smooth. These journals must fit the bearings or bushings within .0005 in. and the shaft must be true throughout its length. V-blocks, a surface plate and a good quality height gauge is used to check the journals and the shaft.

Some of the directly driven compressors have a fitting on the end of the shaft for the mounting of a flexible joint to permit small inaccuracies in motor and compressor alignment.

4-22. VALVE CONSTRUCTION

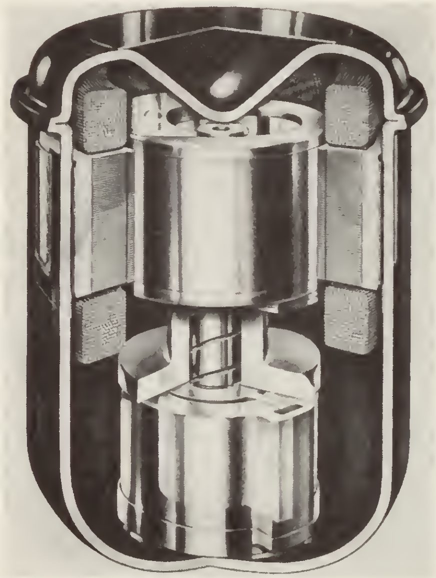
The exhaust valve is usually made of high carbon alloy steel heat treated to provide the properties of a flat spring. It is optically flat with no burrs on either surface. The valve seat is usually part of one of the plates that fasten on the end of the cylinder. This valve seat is made of the same material as the plate. It is constructed as close to the inner surface of the plate as practical to keep the clearance pocket as small as possible. Some valve designs use small springs to assist the closing of the valve and to permit more lift to the valve during those moments when the unit is pumping oil, Figure 4-23.

The rotary compressors do not use an intake valve as such because of the self trapping action of the blade or blades of the compressor. However, due to the pressure differences, compressor oil would be forced back into the suction line to the cooling oil unless a check valve is installed in the intake passages to keep this oil in the compressor. This check valve is usually a disc valve with a small spring locking. One compressor design uses a ball bearing as the check valve.

4-23. CRANKSHAFT SEAL CONSTRUCTION

The seal construction is very similar to the seal construction of the reciprocating compressor. One design has the shaft seal on the high pressure side of the system. The shaft has a shoulder against which a synthetic rubber washer is impressed and a seal ring is then inserted. This seal ring has a pin to keep it from turning on the

shaft. Another construction mounts the bellows and ring on the shaft so that the ring turns with it and the matching face is the end of the main bearing.



4-24. A hermetic rotary compressor. This is a single stationary blade type of compressor. (Frigidaire Div., General Motors Corp.)

4-24. GASKETS

The gaskets are made of the same materials as those of the reciprocating compressor. The thickness of the gaskets is not as important as in some reciprocating compressor gaskets as none are used in critical places.

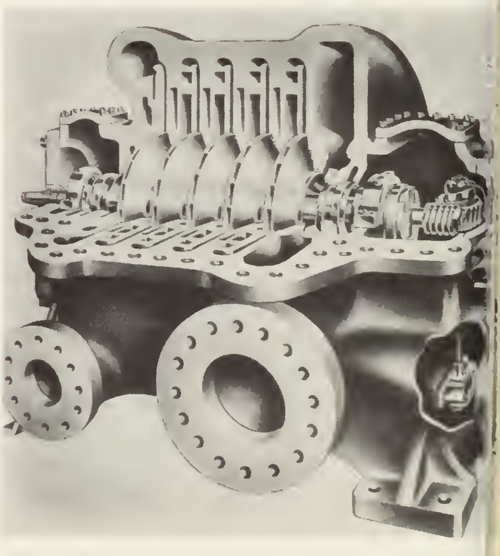
4-25. LUBRICATION ROTARY COMPRESSORS

The success of the rotary compressor is very dependent on the constant film of oil present on the cylinder, roller, and blade surfaces. It is a natural result of the operation of the compressor that oil feeds itself in through the main bearings into the cylinder. The cylinder is therefore located so that the oil level is approximately half way up the main bearings. In all the larger units and even in some of the smaller units, a forced feed lubrication system is used. Some of the units use a separate oil pump, but some take advantage of the pumping action of the blades moving in and out of their slots. If an oil passage is put in an end plate at the time the blade is moving out of the slot and then another passage is connected to slots as the blades move into the slot, oil will be pumped.

The lubricant must be carefully selected. It must be the special moisture free, wax free, unfoaming oil of the correct viscosity for the refrigerant concerned. There is a tendency for carbon to form around the exhaust valve if there are any impurities in the oil.

4-26. HERMETIC ROTARY COMPRESSORS

Rotary compressors are also very popular in hermetic units. Both designs of the rotary compressor have been successfully used in hermetic units. The compressors are directly driven and their design must adapt itself to the

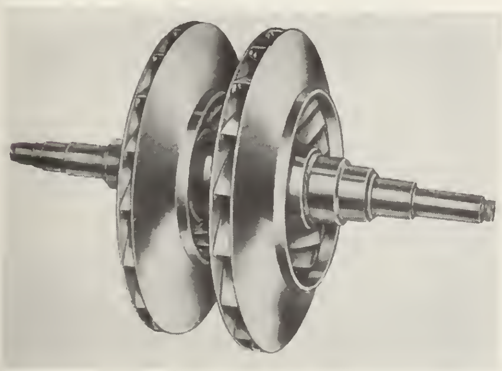


4-25. A centrifugal type compressor. (Carrier Corp.)

higher speed. Therefore the units are better balanced; the valve ports are larger; and the blades, etc; are made of a relatively light material. See Figure 4-24.

4-27. CENTRIFUGAL COMPRESSORS

Centrifugal compressors have been successfully used in large refrigerating systems. This type compressor is based on the principle of the inertia and weight of gas. If a gas is moved rapidly in a circular path, it tends to move outward. This action is called centrifugal force. Therefore if gas is fed into a housing near its center and if a disc with radial blades (impellers) is rapidly turned in this housing, the gas will be forced against the outer diameter of the housing. The pressure difference obtained is rather small so that several of these compressor wheels or impellers are put in series to produce a sufficient volume of gas and to create sufficient pressure differences. There is considerable similarity in appearance between this type of compressor and a steam turbine or an axial flow air compressor for a gas turbine engine. The centrifugal compressor has the advantage of complete simplicity of operation. There are no valves or pistons and cylinders. The only wearing parts are the main bearings, Figure 4-25. Because the pumping efficiency of these compressors varies as the speed, these units are usually run at considerably above the motor speed which necessitates a step-up gear train.



4-26. The rotor (impeller) from a centrifugal type compressor.
(Carrier Corp.)

4-28. STATOR CONSTRUCTION

The stator or casing is usually made of cast iron; it has a varying radius inside to adapt itself to the gas pick up of the impellers. This cylinder contains the main bearings, the oil pressure producing pump, and the intake and exhaust ports for the gases. It also holds the shaft seal where the shaft protrudes from the casing for the power drive attachment.

4-29. ROTOR CONSTRUCTION

The rotor or impeller of the centrifugal compressor is keyed to the compressor shaft. It is made of cast iron or steel and is specially designed to move the gases without exceeding gas velocity limits and without having any gas trapping pockets, Figure 4-26.

4-30. REVIEW QUESTIONS

Answers to these questions may be found in Paragraph 4-31, page 723.

1. What is the purpose of a compressor?
2. What is gained by using a multiple cylinder reciprocating compressor?
3. What is a full floating piston pin?
4. Why must the valves be of light weight?
5. How is the crankshaft joint sealed where it leaves the compressor body?
6. Of what materials are pistons made?
7. Why must the clearance pocket be a minimum volume?
8. What is done to cool the compressor cylinder?
9. What is an internally sprung hermetic compressor?
10. How are hermetic motors usually cooled?
11. Is the stationary blade in a stationary blade compressor really stationary?
12. How many intake strokes and exhaust strokes does the four-blade rotating blade type compressor have per each revolution?
13. Why are the main bearing clearances so closely measured in a rotary compressor?
14. What does a rotary compressor have instead of an intake valve?
15. How may the blades be used to help oil circulation in a rotary compressor?
16. Is it possible to have the crankshaft seal on the high pressure side of a rotary compressor?
17. Why are some rotary compressor blades made of carbon?
18. What would happen if the shaft of a compressor were bent?
19. Does a centrifugal compressor have exhaust valves?
20. Does a centrifugal compressor revolve at higher or lower speeds than a reciprocating compressor?

Chapter 5

REFRIGERANT CONTROLS

An automatically operated refrigerating unit must have a device which will automatically reduce the high pressure liquid refrigerant to a low pressure liquid refrigerant in the correct quantities to keep the cooling unit operating at maximum efficiency and without overloading the compressor. The mechanical or compression system refrigerators have five main types of refrigerant controls:

(a) Low pressure side float
(b) High pressure side float
(c) Automatic expansion valve
(d) Thermostatic expansion valve
(e) Capillary or choke tube

5-1. COMPRESSION MACHINE REFRIGERANT CONTROLS

The modern refrigerating units are almost completely automatic in operation. To obtain this automatic operation, positive methods must be developed for operating the unit to produce proper refrigeration in the cabinet and also for controlling the electric motor which drives the mechanism.

These refrigeration controls may be divided into three classes: (1) the control based on pressure changes, (2) the control based on temperature changes, (3) the control based on volume or quantity changes, or the combination of two or more of the first three.

It is the duty of the automatic controls to maintain the temperature in the refrigerator cabinet within specific limits of 35 F. to 45 F., and to keep the frozen foods compartment between 0 F. to 5 F.

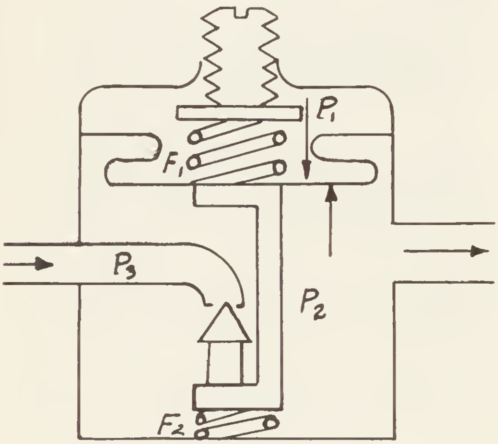
5-2. THE PRESSURE CONTROLLED EXPANSION VALVE

The automatic expansion valve or pressure controlled expansion valve is a refrigerant control whose operation is controlled by the low side pressure of the system, and whose purpose is to throttle the liquid refrigerant in the liquid line down to a constant pressure on the low pressure side. The action of the valve is very similar to a spray nozzle, and while the compressor is running, the liquid refrigerant is sprayed into the cooling unit tubing. Because the cooling unit is never filled with liquid refrigerant, but rather a mist or fog, a system using an automatic expansion valve is sometimes called a "dry" system.

The pressure method is illustrated in Figure 5-1, and shows a flexible bellows connected to the needle of a needle valve and having cooling unit pressure P_2 on the inside with atmospheric or confined gas pressure P_1 on the outside. F_1 spring force tends to open the valve while F_2 tends to close the valve. From the illustration, it may be seen that as the pressure in the cooling coil decreases, the differences in pressures will force the bellows

toward the valve body, and as it is fastened to the needle, it will open the needle valve, and some liquid refrigerant will spray into the coil which, as it evaporates, keeps the cabinet temperature within its design limits.

This opening of the expansion valve occurs only when the compressor is running because this is the only time the pressure is reduced which causes it to operate. The expansion valve cannot flood the low side when the compressor is running, because as soon as the evaporating refrigerant vapor reaches the end of the cooling unit tubing, the motor control (sensitive



5-1. Diagram of an automatic expansion valve showing the various pressures within the valve which cause it to operate.

bulb) located there will cool and open the switch and stop the motor, and the low side pressure will then immediately build up enough to close the expansion valve.

These valves are adjustable to permit the opening of the needle valve over a varying range of pressures (F_1). Expansion valve adjustments must be made for varying altitudes as their operation is influenced by atmospheric pressure. An increase in altitude will require screwing in the adjusting screw. Also different refrigerants require different expansion valve settings.

These automatic expansion valves are made in a variety of designs. The flexible member may be made either as a diaphragm or as a bellows. The diaphragms are made of phosphor bronze and are either clamped or soldered to the valve body. The bellows is made of brass, and it is usually soldered to the body. These flexible elements must move in and out millions of times without any loss of flexibility.

The body of the valve is usually drop forged brass although some are cast. These bodies must be seepage proof.

The liquid inlet is either a soldered connection, a standard flared connection, a large connection, or a pipe thread. A screen is usually located in this inlet, and it is designed for easy removal. This screen is made of brass wire of 60 to 100 mesh, meaning 60 to 100 openings in one inch measurement.

This screen filter in the liquid line will sometimes give trouble by becoming clogged. Notice the double spring arrangement on the needle to balance the forces and give a smoother control of the flow of the refrigerant, Figure 5-2.

To adjust the automatic expansion valve, turn the adjusting screw out (contra-clockwise), which will release the spring pressure or force on the outside of the bellows and enable the needle valve to open only after a lower pressure; therefore, a decrease is on this low pressure side.

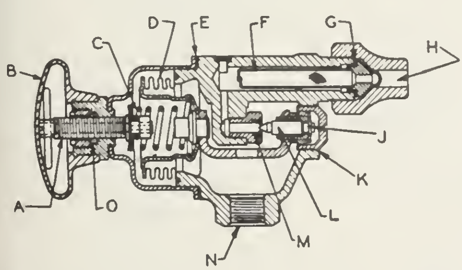
Lowering the pressure on the low side will result in lowering the cooling unit temperature. To raise the cooling unit temperature, turn the adjusting screw in (clockwise) which will increase the spring pressure (force) on the outside of the bellows, and therefore the low side pressure must rise slightly to move the needle back against the seat. These controls can only be used

with a thermostatic motor control.

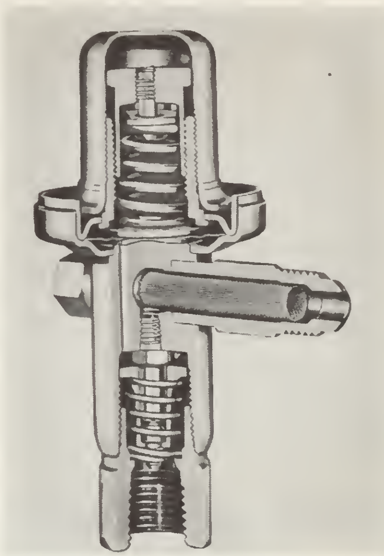
The automatic expansion valve is a good replacement for capillary tube refrigerant controls when a unit is being serviced in the field. These valves are adjustable and are not as critical to the refrigerant charge as capillary tube systems. If an automatic expansion valve is used as a replacement in a hermetic system, one important precaution should be taken. When the motor is a low starting torque type, the head pressure must be reduced during the off-cycle. To accomplish this unloading, a groove is put in the valve seat to permit a small amount of refrigerant to "bleed" past the valve needle during the off-cycle. This "bleed" opening must be large enough to permit pressure balancing during the off-cycle but must be small enough to permit control of the refrigerant when the system is at its lowest operating pressure.

5-3. THE BELLOWS TYPE EXPANSION VALVE

Figure 5-2 illustrates a bellows type automatic expansion valve. The body is made of special alloys (usually Stellite needles and Monel metal seats). The valves have softer seats than needles to eliminate as much as possible the wearing of a shoulder on the needle. The spring "C" is attached at both ends, eliminating a spring inside the refrigerant space. The needle is mounted in a ball and socket to insure full seating by allowing the needle to align itself with the seat. The bellows, made of special brass, is very flexible and is soldered to both the body and the disk.



5-2. A pressure-controlled expansion valve A. Adjusting screw; B. Rubber cap; C. Lock joint; D. Bellows; E. Gasket; F. Screen; G. Plug; H. Liquid inlet; J. Needle shoulder; K. Plug; L. Needle; M. Seat; N. Refrigerant outlet; O. Packing.
(Detroit Controls Co.)



5-3. A type of pressure controlled expansion valve using a diaphragm in place of bellows

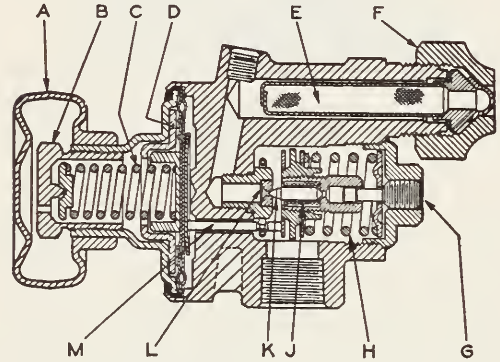
This bellows is made of stock .005 in. to .010 in. thick. It is carefully made in a series of rolling operations. The liquid line is usually 1/4 in. outside diameter (O.D.) and is fastened to the valve at "H" by a special nut permitting easy removal of the screen. Note how the external surface of the bellows is sealed at "O" and "B" to insure that moisture will not enter, then freeze on the bellows and interfere with the accurate operation of the valve. The valves may be attached to the cooling coil either by means of threaded fittings or by two bolt flanges. Flanges sealed with lead gaskets are preferred.

The automatic expansion valve is used chiefly on some older domestic refrigeration and on automobile air conditioning equipment.

5-4. THE DIAPHRAGM TYPE EXPANSION VALVE

Figure 5-3. Note that the diaphragm is made in two discs, and metal guards are placed against the discs to protect them. The valve is designed with stops to prevent too great movement of the diaphragm. The diaphragm is placed into the body recess; the cap is put in place, and the assembly is soldered. Note that the diaphragms have concentric corrugations to improve their flexibility.

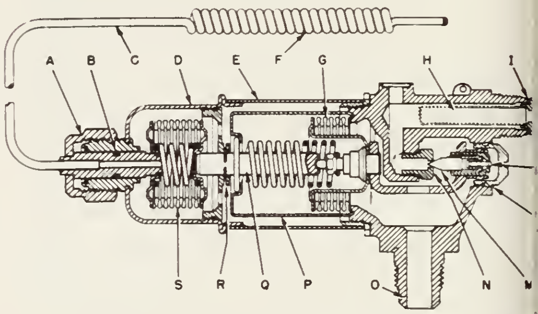
Another diaphragm expansion valve design is shown in Figure 5-4. The diaphragm movement is limited by the body and the cap. The cap or cover plate is crimped over the edge of the body and the assembly is soldered. The diaphragm has a disc on the low pressure side, and this disc acts on pins that move the needle away from the seat and allow the pin to contact the seat again. The inlet is a 1/4 in. flare connection and the outlet is an internal 1/4 in. pipe thread.



5-4. A popular diaphragm type automatic expansion valve. A. Rubber cap; B. Adjusting screw; C. Adjusting spring; D. Diaphragm; E. Screen; F. Inlet nut; G. Factory adjustment; H. Spring; J. Spring; K. Needle; L. Seat; M. Pin.
(Detroit Controls Co.)

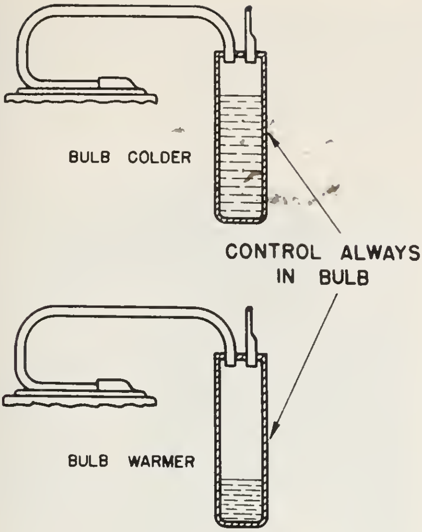
5-5. THE THERMOSTATIC EXPANSION VALVE

Thermostatic expansion valves, which were developed in the late twenties are rapidly becoming the leading multiple cooling coil refrigerant control. This control was originally produced to eliminate trouble with oil binding that was experienced with low side float installations.



5-5. A thermostatic type expansion valve. A. Adjusting nut, B. Seal ring, C. Capillary tube, D. Bellows housing, E. Spacer, F. Thermal bulb, G. Body bellows, H. Screen, I. Gasket, J. Refrigerant inlet, K. Needle pin, L. Sealed fitting, M. Needle, N. Seat, O. Cooling Coil connection, P. Inner spacer, Q. Spacer rod, R. Snap ring, S. Thermal bellows.
(Detroit Controls Co.)

The theory of the thermostatic expansion valve is as follows: a power element, capillary tube, and thermostatic bulb apparatus is mounted into a typical expansion valve and causes the valve to keep the coil filled with refrigerant rather than to maintain a definite low side pressure. The thermal expansion valve under any circumstances does not attempt to regulate the low side pressure, but rather controls the filling of the cooling coil with refrigerant, and the compressor establishes its own pressure upon this refrigerant, Figure 5-5. This control was first used for the methyl chloride systems, but its inherent advantages soon led to its adoption for all multiple installations. It has one distinct advantage over the low side float multiple system in that several different temperatures may be obtained without using any other special device. This may be accomplished by starving the coils in



5-6. The thermal element of a thermostatic expansion valve. There is enough refrigerant to insure liquid refrigerant in the control bulb at all times.
(Detroit Controls Corp.)

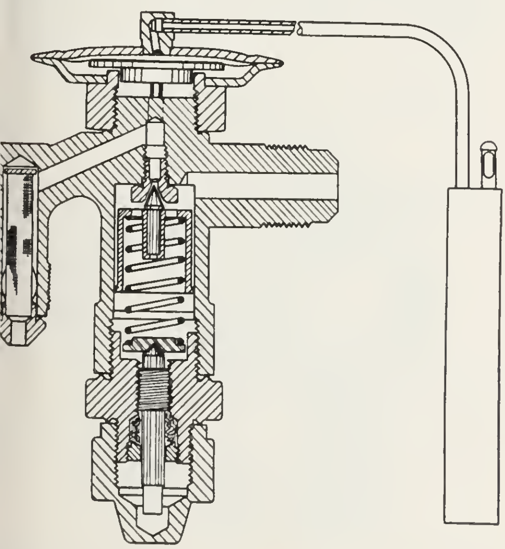
the cabinets desired to be kept at a warmer temperature.

The construction of this valve consists of a brass body into which the liquid line and cooling unit connections are built. In this body is located the needle and seat, the former of which is joined to a flexible metal bellows or diaphragm. This bellows, in turn is actuated by a non-heat conducting rod connected at the other end to a sealed bellows (power element), which is joined to the thermostatic bulb by means of a capillary tube; all are carefully sealed, Figure 5-6. This thermostatic element must be charged with the same refrigerant that is used in the system. Each manufacturer has a code for identifying the refrigerant with which the thermostatic element is charged. Some use letters such as S, M, F, etc., indicating sulphur dioxide, methyl chloride, or Freon 12. Others use colors or numbers to denote the charge. The whole valve is sealed to prevent moisture seeping into any part. A screen or strainer is always located between the liquid line connection and the orifice to keep dirt away from the needle and seat of the valve. Some air-conditioning systems use as many as six of these thermostatic expansion valves on one cooling coil.

Another thermostatic expansion valve is shown in Figure 5-7. It is of the single diaphragm type. Note the pins that carry the diaphragm action to the needle. The liquid inlet is on the left, and the coil connection is on the right.

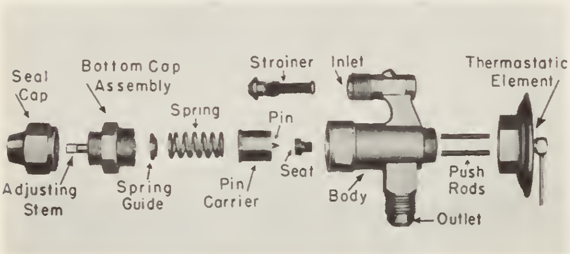
An exploded view of the valve is shown in Figure 5-8. The pin or needle is made of Hastelloy, the seat is brass, the body is brass. Note that the inlet flare connection is mounted on the screen.

The proper installation of the thermostatic expansion valve is the first factor to obtain satisfactory usage. The operation of the valve is simple. The bulb of the thermostatic expansion valve should be located at the outlet of the cooling coil. When the bulb warms the refrigerant vaporizes some of it and builds up a pressure in the power element by means of the capillary tube connection, and the bellows expands. This expansion forces the needle open,



5-7. A thermostatic expansion valve. Note the flared connections and the adjusting screw.
(Sporlan Valve Co.)

admitting liquid refrigerant into the cooling coil, Figure 5-9. This continues until the whole coil is cooled, and the suction line starts to cool. As soon as the suction line, to which the power bulb is attached, becomes cooled sufficiently, the pressure in this bulb decreases, due to condensation of its refrigerant, which relieves the pressure in the bellows. This causes a contraction of the bellows, and the expansion valve is shut off, leaving the cooling coil filled with liquid refrigerant vapor. The refrigerating mechanism now lowers or decreases the low side pressure, for it continues to run until the pressure motor control or thermostatic motor cuts out, giving the temperature desired. When the condensing



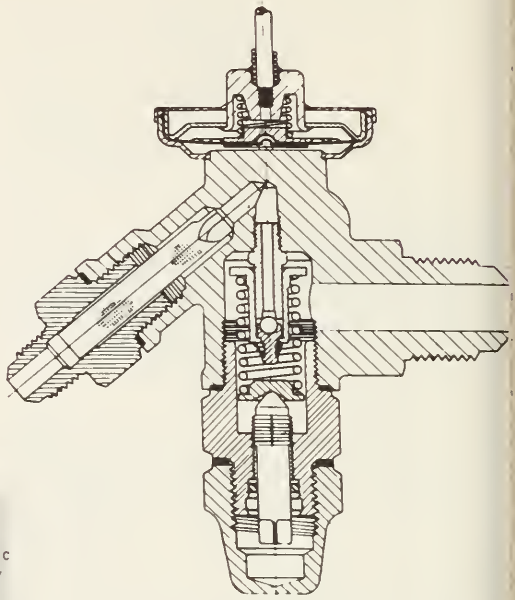
5-8. The various parts of a thermostatic expansion valve of the diaphragm type. Note the push rods that carry the diaphragm movement to the pin carrier.
(Sporlan Valve Co.)

unit stops, the thermostatic expansion valve closes. This closing is accomplished by the low side pressure equalling the thermal bulb pressure the instant the condensing unit stops. This closing action is important; otherwise the cooling coil would become flooded with refrigerant.

The needles are usually made of Stellite Hastelloy, or stainless steel while the seats are made of stainless steel, Monel or brass.

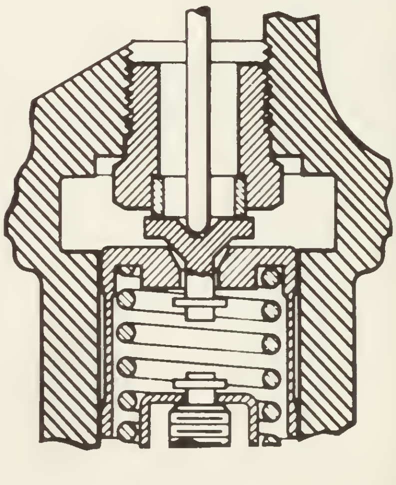
The needles are usually sharp pointed cones but spherical orifice closers, and flat orifice closers have also been used.

The conical needle is popular for small capacity valves while the "ball bearing" needle or the flat needle is used in larger valves, Figure 5-10.



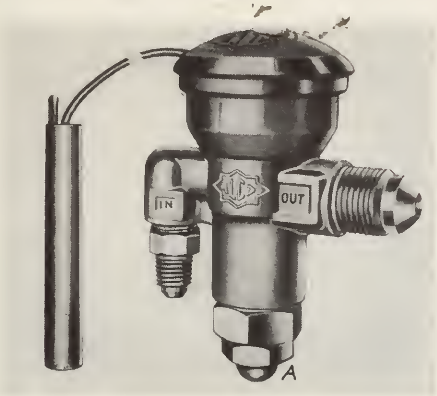
5-9. A diaphragm type thermostatic expansion valve. A ball is used to the needle and a long cage guides the movement. Pins carry the diaphragm movement to the needle cage.
(Automatic Products Co.)

Most of these valves are equipped with an adjustment. One of the adjustments is designed to move the power



5-10. A large capacity thermostatic expansion valve orifice.
(Detroit Controls Corp.)

element against the expansion valve bellows. If it is turned out or contra-clockwise, the power element will be moved away from the expansion valve bellows. This action will "starve" the



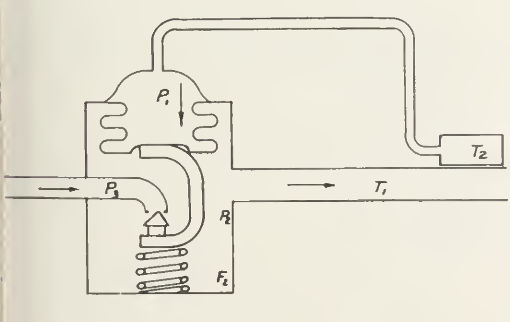
5-11. A thermostatic expansion valve with the valve adjustment in the body of the valve, A. (Alco Valve Co.)

cooling coil or will result in closing the needle before the coil becomes full of liquid refrigerant.

Another type valve has the adjusting screw in the body of the valve, Figure 5-11. In this type the cooling coil will receive more refrigerant if the adjusting screw is turned out, and the coil will be "starved" if the adjusting screw is turned in.

5-6. THERMOSTATIC EXPANSION VALVE PRINCIPLE

The thermostatic expansion valve



5-12. Diagram of a thermostatic expansion valve showing the various pressures within the valve which causes it to operate.

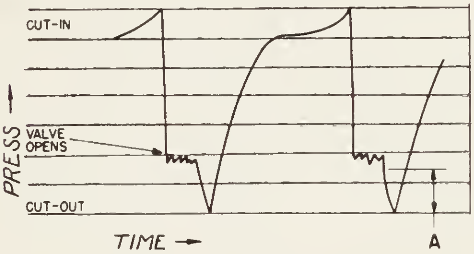
works on the pressure difference basis; that is, the accumulated pressure difference or force difference between the element bellows and the body sealing bellows, Figure 5-12. With the unit running, the refrigerant, (T_2) in the expansion valve thermostatic element is usually about 10 F. warmer than the refrigerant in the cooling coil (T_1) producing the different pressures and therefore the different forces. This means that the unit pressure in the element (P_1) is greater than the unit pressure (P_2) in the cooling coils (both containers using the same refrigerant). Therefore, to obtain balanced total pressures or force between the two bellows, the element control bellows sometimes has a smaller area (diameter) than the sealing bellows. This temperature (pressure) difference is often described as the superheat of the bulb over the coils refrigerant temperature while the unit is running.

When the compressor stops, the low side pressure and the element pressure tend to equalize. The total expansion valve bellows pressure or force therefore overpowers the element bellows pressure, and the needle is forced firmly into the seat stopping the flow of refrigerant. The needle will now stay closed until the element force builds up enough to overcome the low side force. This can only happen when the unit is running. This prevents the flooding of the low side while the compressor is idle if the valve is adjusted correctly.

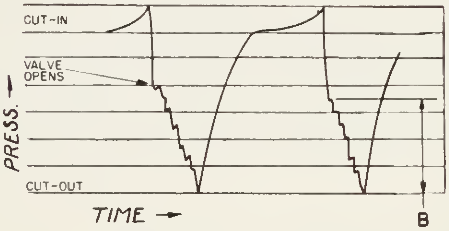
With the adjustment turned to enable the needle to easier seat itself while the unit is running, the needle will close even though there is a greater temperature difference (about 15 F. temperature difference) between the refrigerant in the coil and that in the bulb, Figure 5-13. The cooling coil refrigerant liquid will not reach the bulb location in this case, because the low pressure gas only will be cold enough to reduce the element pressure

to the closing point. The coil will then be starved and the needle will shut off before the coil becomes full of liquid refrigerant.

When the adjustment is turned to move the needle away from the seat one or two revolutions, the temperature of

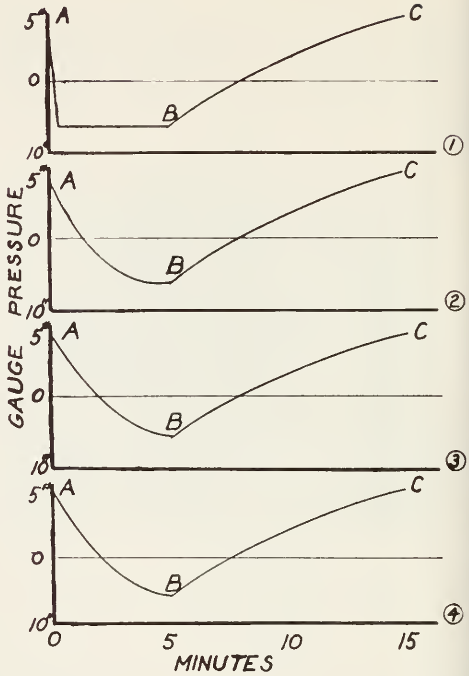


5-13. A low side cycle when a large superheat adjustment is used. (A) represents the small pressure drop between the opening of the valve and the cut-out point. (Detroit Controls Corp.)



5-14. A thermostatic expansion valve adjusted to a small superheat. Note that the distance "B" represents the pressure drop on the low side after the valve starts to function.

the element refrigerant must become nearer that of the cooling coil refrigerant (5 F. to 7 F.), Figure 5-14. The coil must now become more than full of liquid refrigerant to bring the temperature (pressure) difference down to this value. The coil will be completely flooded, and some liquid may even go into the suction line. This adjustment is sensitive and should never be turned more than one-quarter of a turn at a time. Some thermostatic expansion valves use diaphragms of equal diameter instead of bellows. In this case, the valve is closed when the unit is idle by means of springs working



5-15. Low side pressure time graphs for various refrigerant controls. Expansion valve (pressure); 2. Low side float; 3. High side float; 4. Thermostatic expansion valve; A. Cut-in point; B. Cut-out point; C. Cut-in point.

in favor of the low-side pressure pressing on one side and the element pressure on the other side. Figure 5-15 illustrates the low-side pressure behavior when the various refrigerant controls are used.

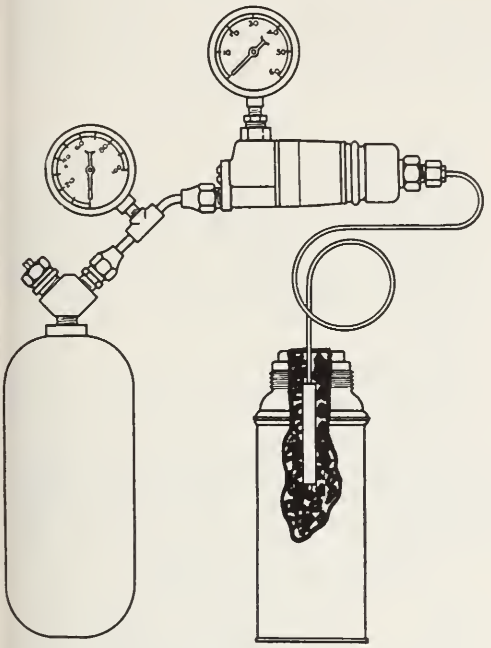
5-7. TESTING THE THERMOSTATIC EXPANSION VALVE

A simple method of testing thermostatic expansion valves in the field recommended by the Detroit Controls Company is as follows:

In most cases the regular service kit contains all of the necessary equipment, Figure 5-16. The equipment required is as follows:

1. Service drum of Freon 12, or Methyl Chloride (in the shop a supply of clean dry air at 75 to 100 pounds pressure can be used in place of the service drum. The service drum is

merely for the purpose of supplying pressure, and for this reason the refrigerant used does not have to conform with the valve being tested; in other words, a drum of Freon 12 would be satisfactory for testing with SO_2 Methyl Chloride or Freon 12 valves.).



5-16. A method of testing thermostatic expansion valve.

2. High pressure and low pressure gauges. The low pressure gauge should be accurate and should be in good condition so that the pointer does not have too much lost motion. A high pressure gauge is not absolutely necessary but is recommended in order to show the pressure on the inlet of the valve.

3. A small quantity of finely crushed ice is necessary, and one of the most convenient ways of carrying this around is to keep it in a thermos bottle. Thermos bottles are available with large size necks. If such a container is completely filled with crushed ice, it will last easily for twenty-four hours. Whatever the container is, it should be completely filled with crushed ice. Do not attempt to make this test with the container full of water and a little crushed ice floating around on the top.

Proceed as follows to adjust the valve:

1. Connect the valve as shown with the low pressure gauge screwed loosely into the adapter on the expansion valve outlet. The gauge is screwed up loosely to provide a small amount of leakage through the threads.

2. Insert the bulb in the crushed ice.

3. Open the valve on the service drum and be sure that the drum is warm enough to build up a pressure of at least 70 pounds on the high pressure gauge connected in the line to the valve inlet.

4. The expansion valve can now be adjusted. The pressure on the outlet gauge should be different for various refrigerants as follows:

Freon 12. . . . . .22 pounds
Methyl Chloride . . . . . .15 pounds
Sulphur Dioxide . . . . . . 3 pounds

When making the adjustment, be sure to have a small amount of leakage through the low pressure gauge connection.

5. Tap the body of the valve lightly in order to determine if the valve is smooth in operation. The needle of the gauge should not jump more than one pound.

To test the needle for leaks, screw the gauge up tight to stop the leakage through the threads and determine if the expansion valve closes off tightly. With a good valve the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve, the pressure will build up rapidly until it equals the inlet pressure.

The power element may be tested by loosening the low pressure gauge to permit leakage through the threads and then removing the power element bulb from the crushed ice and warming it up with your hand, or by putting it in water at about room temperature. The pressure should increase rapidly show-

ing that the power element is operating.

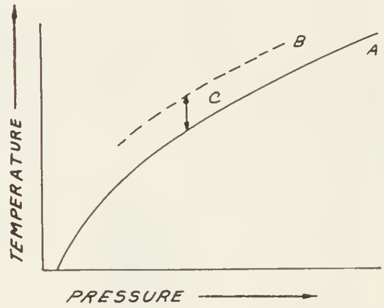
Note: With the new gas charged, (a small quantity of refrigerant) expansion valves, the amount of charge in the power element is limited, and the pressure will not build up above the specified pressure. This pressure is always marked on the valve body and must be considered when testing gas charged valves.

The body bellows is tested with high pressure showing on both gauges as outlined in the preceding paragraph. A leak is detected by loosening the packing nut and using a Halide leak detector to detect the escape of gas. When making this test, it is important that the body of the valve has a fairly high pressure and also the gauge and other fittings are screwed up tight to eliminate leakage at other points. Leakage can also be detected by the use of oil or soap suds.

5-8. THE NORMAL CHARGE POWER ELEMENT

The thermostatic element of the thermostatic expansion valve is very accurately made. As mentioned before, it is essential that the element is charged with the same refrigerant as is in the system. This similarity enables the valve to maintain a constant superheat setting even though the low side pressures and temperatures change, Figure 5-17.

One problem encountered with the thermostatic expansion valve is that with a normal refrigerant charge (1/2 liquid and 1/2 gas) the element will always overload the condensing unit when the refrigerating machine first starts up after a long shut down period. For example, if a one H.P. unit has been idle for several days, and the cabinet, the cooling coil, and the condensing unit are all at the ambient temperature (room temperature), and the unit is then started, the low side pressure will be very high. And it will continue to be high as the cabinet slowly cools off. The reason for this long overload is that the expansion valve will keep the coil full of liquid refrigerant whether the coil is at 75 F. or 0 F. That is if the coil refrigerant is at 75 F., the valve will open; if the cabinet temperature is 85 F. This prolonged overload sometimes causes the refrigerating unit to fail (motor burn-outs, etc.).

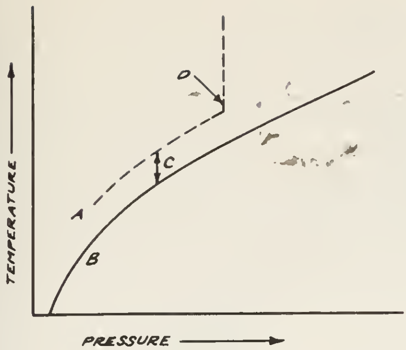


5-17. The constant superheat setting of a thermostatic expansion valve. A. Vapor pressure curve of the refrigerant in the cooling coil; B. The vapor pressure curve of the refrigerant in the bulb at the same moment; C. The superheat difference (normally 10 F.).

Another problem encountered with the normal charged element is that the element sometimes loses its sensitivity, because the liquid refrigerant collects at the bellows or diaphragm. For example, if the valve body is located in a sheltered spot on the coil and the bellows or diaphragm end of the element becomes colder than the bulb all the liquid refrigerant will settle at the bellows or diaphragm, and the bulb being only filled with gas cannot respond to coil temperature changes.

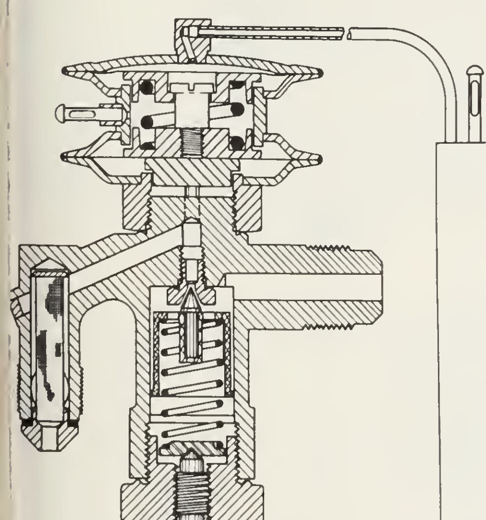
5-9. THE GAS CHARGED POWER ELEMENT

One way to eliminate the overloading of a condensing unit during a "pull-down" from warm conditions is to use a thermal unit having a very small charge of refrigerant. This



5-18. The action of a gas charged thermostatic expansion valve thermal element. A. Maximum pressure in the thermostatic element; B. The path of the low side pressure and temperature as the unit "pulls-down"; C. The path of the thermal element pressure and temperature below the maximum pressure setting until the constant superheat setting is reached "D."

harge is small enough so that at a certain pre-determined temperature, all of the refrigerant is in a gas state, and the element pressure will not increase above this point. For example,



-19. A thermostatic expansion valve with a collapsible element between the element mechanism and the needle mechanism. Above a certain low side pressure, the spring will collapse if the element pressure increases. (Sporlan Valve Co.)

if just enough refrigerant is put in the element to produce a maximum pressure of 40 psig the element pressure will never exceed this value. If the low side pressure ever exceeds this pressure, the valve will not open, Figure 5-18. There is a tendency for the small amount of liquid in this type of element to collect at the bellows and diaphragm, and the valve may lose its sensitivity.

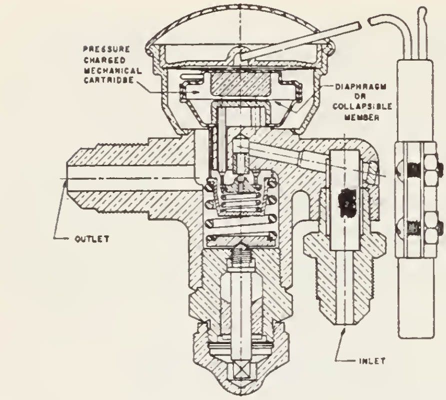
5-10. THE LIQUID CHARGED POWER ELEMENT

For those installations where the body of the valve is exposed to colder temperature than the bulb, a liquid charged element has been developed. This element is completely filled with liquid refrigerant. Under no conditions can the sensitive bulb be emptied of liquid. This valve operates under hydraulic principles at its lower temperatures.

5-11. PRESSURE LIMITERS

Another method used to prevent overloading the condensing unit is to put a collapsible element between the thermal element mechanism and the needle mechanism. This little sealed bellows is designed to collapse at a certain force, element pressure or low side pressure. Therefore, if this collapsible element is designed to collapse at 40 psig of the diaphragm or bellows, the needle will close if the low side pressure ever exceeds this amount regardless of the element temperature or pressure. The operation is similar to that shown in Figure 5-18. This type thermostatic expansion valve is shown in Figure 5-19.

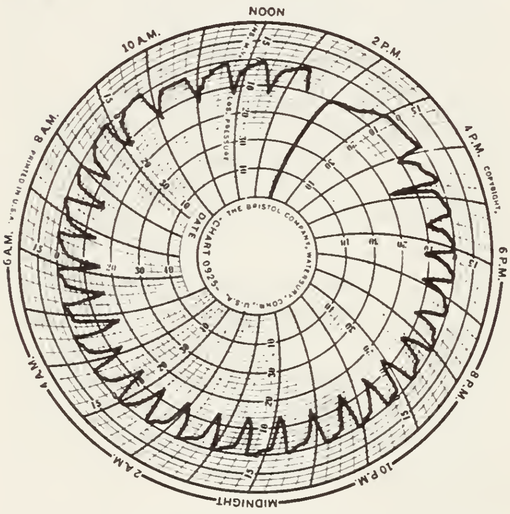
A gas charged collapsible element can also be used to provide a limit as to the pressure which will open the valve. When the pressure in the low side exceeds a certain set value, the



5-20. A diaphragm type thermostatic expansion valve with a collapsible element mounted between the thermal element and the valve.
(Alco Valve Co.)

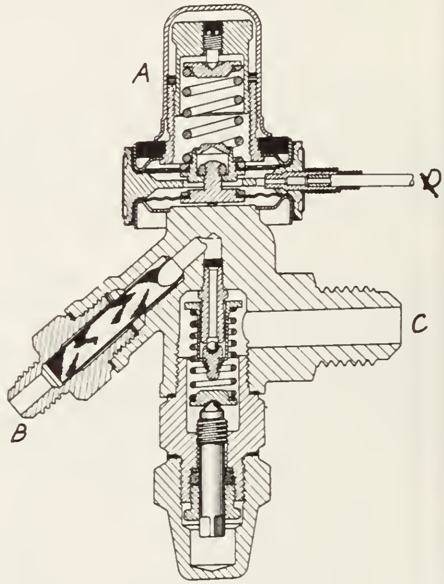
diaphragm will collapse, Figure 5-20. The gas used is a non-condensable gas and obeys Charles' and Boyle's Laws only.

An example of how the pressure limiting device prevents a long running time at excessive low side pressures when the refrigerator is warm is shown in Figure 5-21. The cycle record shows a pressure drop from our 50 psi to 10 psig in just a few minutes. The unit then ran for two hours before a thermostat shut it off.



5-21. A cycle diagram of a home freezer unit equipped with a pressure limited thermostatic expansion valve and a thermostat motor control. The unit was started warm at 2 P. M. Note the quick reduction of pressure until the valve opened at 10 psig.
(Sporlan Valve Co.)

Another type of pressure limiter thermostatic expansion valve is shown in Figure 5-22. This valve has an adjustable pressure limiter (A). Above a certain set pressure setting at (A) the spring above the diaphragm will compress instead of the valve needle being

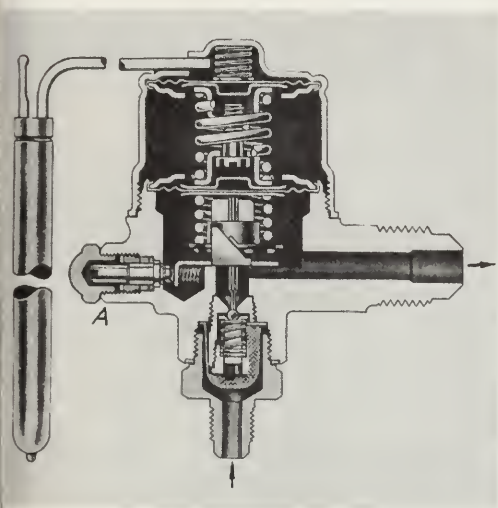


5-22. A thermostatic expansion valve with an adjustable pressure limiter device. A. Pressure limiter adjustment, B. Liquid inlet, C. Cooling coil connection, D. Thermal bulb connection.
(A-P Controls Corp.)

opened. The liquid inlet is at (B) and the cooling coil connection is at (C). The capillary tube and thermal bulb is not shown but the connection is at (D). Another spring loaded pressure limiter is shown in Figure 5-23. The pressure limiter assembly is shown in Figure 5-24. It will stay as a rigid rod and open and close the valve until the pressures in the low pressure side and in the thermal element are greater than the pressure of the spring.

Some thermostatic expansion valves have a thermal element "cross" charge. A different refrigerant is put in the thermal element. The pressure

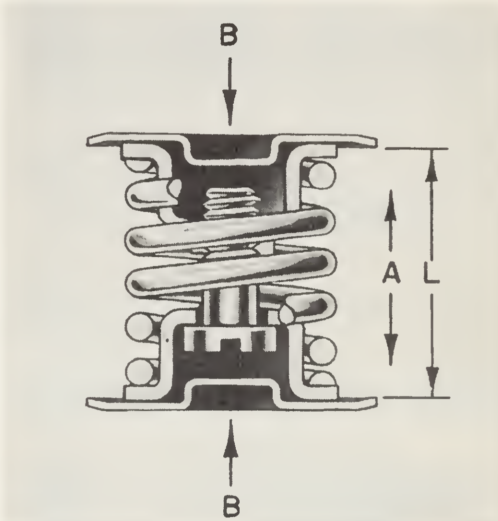
temperature curve of this refrigerant is such that the valve has high superheat when the coil is warm and the low side pressures are high. Then as the coil cools and the low side pressure reduces, the superheat setting is reduced, Figure 5-25. This cross charge is mainly used in low temperature installations. The valves are usually liquid charged valves. One must be very accurate in choosing the correct valve and the correct size valve for each installation.



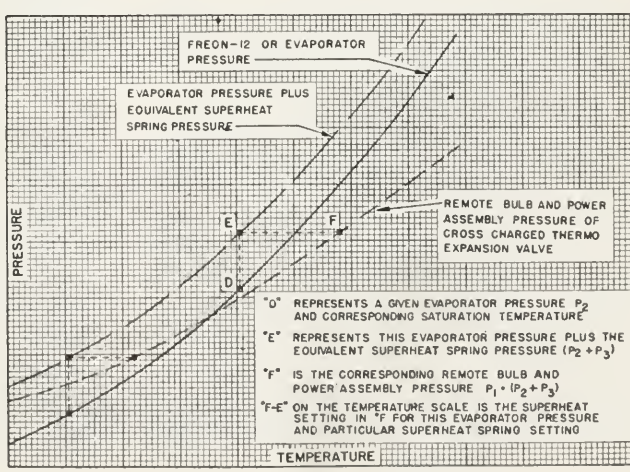
5-23. A valve with a spring loaded pressure limiter. A. Superheat adjustment. (Detroit Controls Co.)

5-12. THE POWER ELEMENT MOUNTING

The location and the actual mounting of the power element bulb is very important. The bulb must be in good thermal contact with the cooling coil outlet, Figure 5-26. The bulb should be mounted on the top of the suction line so its liquid is close to the suction line. If it is necessary to mount the



5-24. The pressure limiter device. With the adjusting screw set to produce length (L), the forces (B) will collapse the spring (compress it) when they exceed the forces (A). (Detroit Controls Corp.)



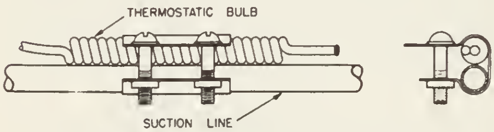
5-25. A graphical picture of how a cross charge thermostatic expansion valve operates. (Alco Valve Co.)

bulb on a vertical suction line, the capillary tube should come out the top of the bulb. To keep the bulb from being influenced by the air or liquid being cooled the bulb is insulated. Special rubber forms are available to put around the bulb, and the line or friction tape can be used to insulate the bulb so that only the suction line temperature can influence the bulb.

Metal straps, copper, and nonrusting machine screws are usually used to fasten the bulb to the suction line. The bulb must have excellent thermal contact with the suction line. The connection must be clean and tight.

5-13. THERMOSTATIC EXPANSION VALVES CAPACITIES

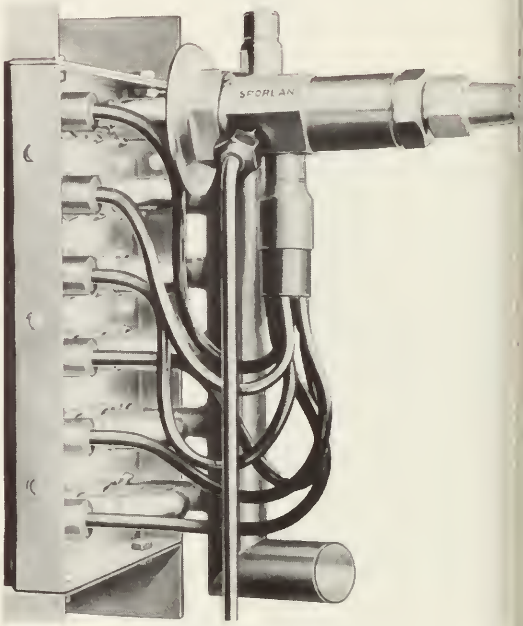
One type of valve has one standard body, but it has an easily replaced needle and seal assembly. These assemblies come in a variety of sizes



5-26. The correct way to fasten a thermal bulb to a suction line.
(Detroit Controls Corp.)

(orifice sizes). The larger the orifice size the more liquid refrigerant can be fed into the coil per unit of time.

The valves are rated in tons of refrigeration. However, the same orifice usually has three different tonnage capacities. (This change in capacity is because the amount of liquid that will flow depends on the difference between the high pressure on the condensing side and the low pressure on the low pressure side.) Therefore, if it is a Freon 12 system, a valve that has a 1/2 ton rating at a 13 psig on low side pressure, domestic will have a 3/4 to 1 ton capacity at 5 in. vacuum (frozen food units) and a 1/3 ton capacity at 40 lbs. per sq. in., assuming 130 lbs. per sq. in. head pressure; in the first case there is a 130-13 = 117 lb. pressure difference; then in the second case it is $130 + 2\frac{1}{2}$ (5 in. vacuum = $2\frac{1}{2}$ lbs.) = $132\frac{1}{2}$ lb. pressure difference, and in the last case it is 130-40 = 90 lb. pressure difference.



5-27. A thermostatic expansion valve with a distribut[illegible] incorporated in the valve body. The inlet fitting is [illegible] the top. The cap covering the adjusting screw is [illegible] the right. The small line attached to the center of th[illegible] valve with a flare nut is the equalizer tube.
(Sporlan Valve Co.)

It is very important to put a valve o[illegible] the correct capacity on a coil. If th[illegible] valve orifice is undersize, the coil wil[illegible] be starved regardless of the superhea[illegible] setting, and the full capacity of the coi[illegible] cannot be obtained.

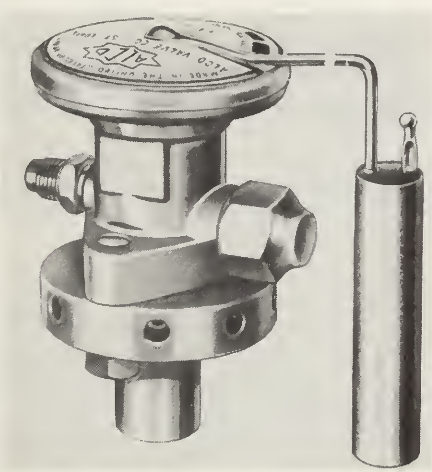
If the orifice is oversize, the valv[illegible] will "hunt" or surge. When the valv[illegible] opens, too much refrigerant passes int[illegible] the cooling coil, and the coil will swea[illegible] or frost down into the suction line befor[illegible] the thermal element can close th[illegible] valve. If one tries to correct this con[illegible]

dition by increasing the superheat setting, the coil will be starved much of the time, and full efficiency cannot be realized.

5-14. SPECIAL THERMOSTATIC EXPANSION VALVES

There have been many thermostatic expansion valve designs on the market. These designs help the valve serve many purposes.

One valve combines a distributing tube or manifold in the body of the valve, Figure 5-27. This model is popular for air conditioning applications. The design must be carefully



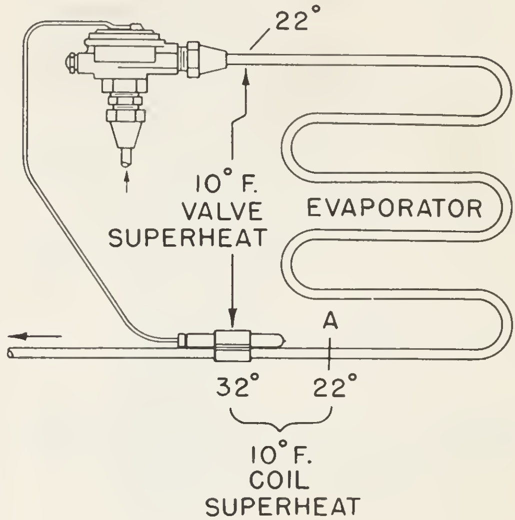
5-28. A thermostatic expansion valve with multiple outlets and an external equalizer connection. Note the packing around the valve stem and the method used to adjust the superheat setting.
(Alco Valve Co.)
(Detroit Controls Corp.)

engineered, as each tube must receive an equal amount of refrigerant.

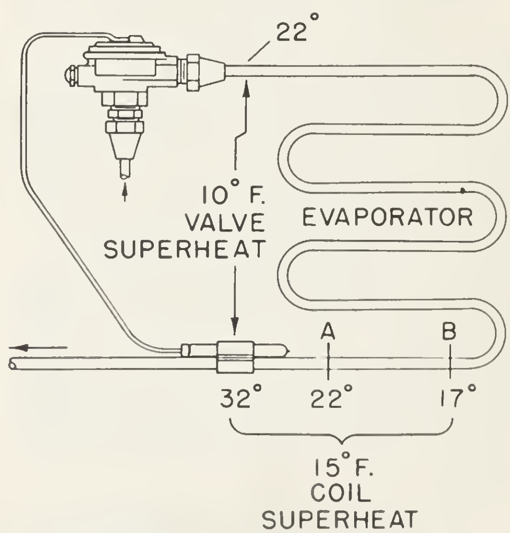
Another design uses an equalizer tube. Figure 5-28 shows a valve with a multiple outlet, and an external equalizer.

When a thermostatic expansion valve is installed in a normal situation with a 10 F. superheat, the settings may be as shown in Figure 5-29.

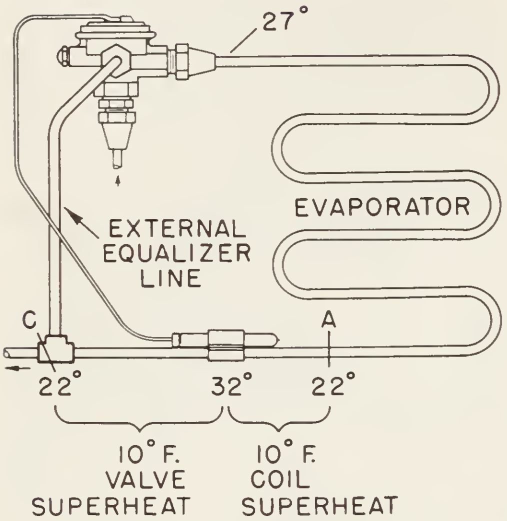
It has been shown that when there is an appreciable pressure drop in the cooling coil, the pressure on the inside of the valve body will be higher than the pressure of the boiling refrigerant near



5-29. A normal superheat setting. A. indicates the place the liquid refrigerant reaches before the valve closes.
(Detroit Controls Corp.)



5-30. A starved cooling coil due to excessive pressure drop in the cooling coil. The liquid reaches point B at 17 F. and the gas warms to 22 F. at which time the valve closes.
(Detroit Controls Corp.)



5-31. An equalizer tube will produce the same coil superheat as the valve superheat. The pressure under the bellows or diaphragm is the same as the suction line pressure at the thermal bulb location. (Detroit Controls Corp.)

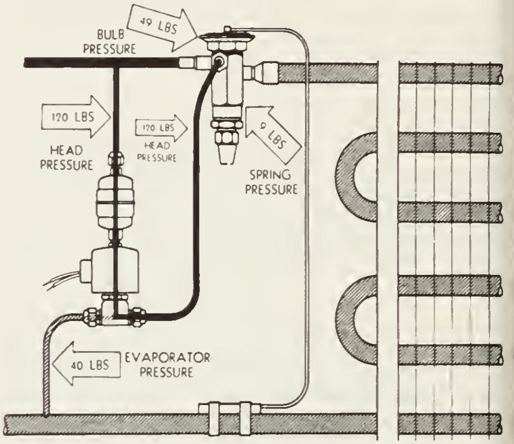
the bulb location. This action tends to starve the cooling coil due to the higher than normal valve body pressure, Figure 5-30.

Although the valve is adjusted for a 10 F. superheat, the excessive pressure drop actually results in a 15 F. superheat setting and a starved coil.

If a small tube ($\frac{1}{4}$'' O.D.) is connected to the suction line and then tapped into the expansion valve so that the two pressures are equal, the valve will operate much better, Figure 5-31.

The equalizer tube is connected to the low side pressure side of the bellows or diaphragm. Therefore, even though the low side pressure drop in the coil is high, the pressure operating the valve is the same as the pressure in the suction line at the thermal bulb setting.

Another problem encountered with thermostatic expansion valves is their tendency to open intermittently during an off-cycle. To prevent this occurrence, one may impose the high side pressure on the valve to force it closed. A solenoid valve is used to control this pressure. A special solenoid valve connected into the equalizer tubing is shown in Figure 5-32. The solenoid valve electrical circuit is opened as the compressor motor circuit opens. The solenoid core falls and closes the

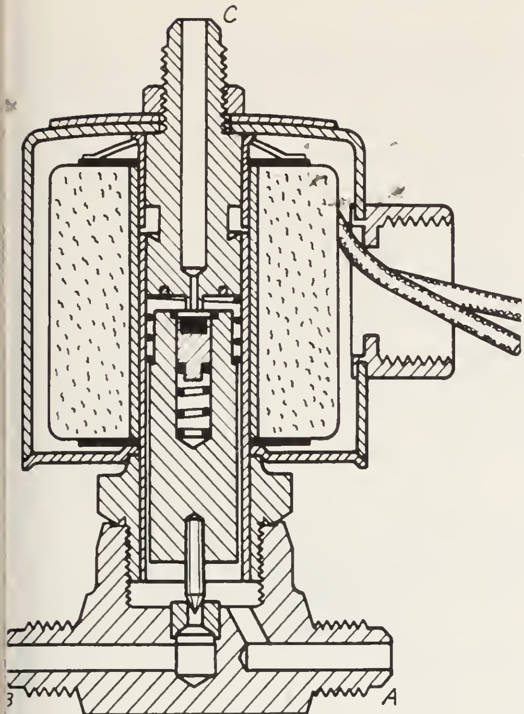


5-32. A special solenoid valve that controls the equalizer tube. The solenoid valve is not energized in the illustration and the high pressure gas is against the bottom of the valve diaphragm. (Sporlan Valve Co.)

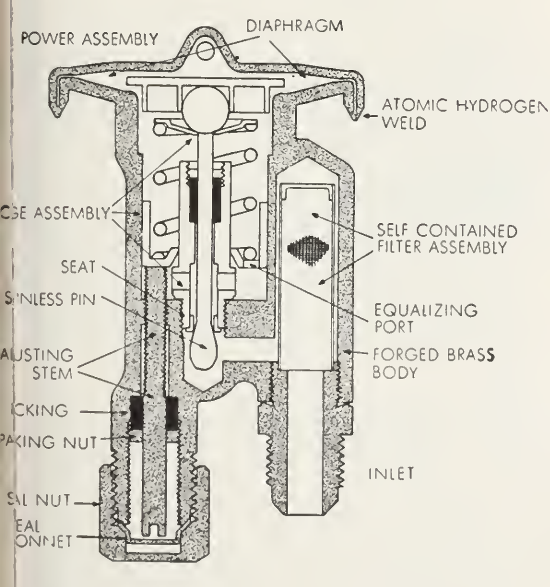
equalizer tube to the suction line. The high pressure refrigerant enters the top of the solenoid valve and passes up the equalizer tube and forces the thermostatic diaphragm up allowing the valve to close. Figure 5-33 shows a cross-section of the special solenoid valve.

This arrangement permits using a small solenoid valve to control large capacity systems.

A valve that has been made with an unusual adjustment is shown in Figure 5-34. This valve uses a needle fastened to a disc and a ball so the same spring that pushes the diaphram against the element pressure will force the needle against its seat. The other end of the spring is encased in a washer that is positioned by an adjusting stem. When this adjusting screw is turned in or clockwise, it increases the superheat



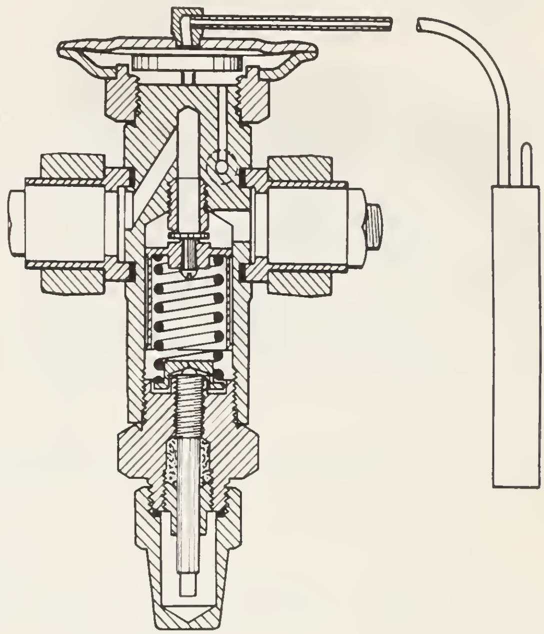
5-33. A three-way solenoid valve used to control an equalizer tube. When energized the openings A and B are connected. When not energized openings C and A are connected.
(Sporlan Valve Co.)



5-34. A thermostatic expansion valve with a superheat adjustment that adjusts the spring force. When the screw is turned in, the superheat difference will increase.
(Alco Valve Co.)

setting or starves the coil. The outlet to the cooling is not shown in the illustration.

A large capacity valve is shown in Figure 5-35. It has flanged refrigerant



5-35. A large capacity thermostatic expansion valve equipped with an equalizer tube fitting and a disc-type valve.
(Sporlan Valve Co.)

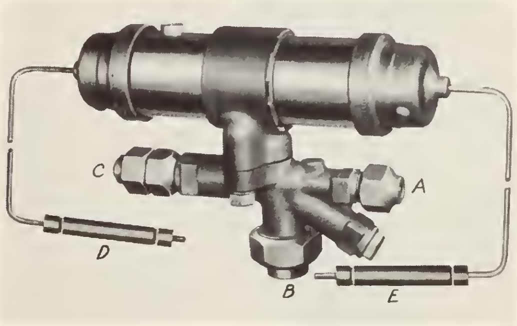
line connections bolted together and gasketed. Instead of a needle and seat, it has a disc valve and seat. An equalizer tube connection is shown in the upper right part of the body.

When thermostatic expansion valves are used in low temperature installations, the pressures are too low to create enough force to efficiently open and close the valve. A differential valve which operates on the difference in temperature at two coil positions solves this difficulty, Figures 5-36 and 5-37.

5-15. LOW PRESSURE SIDE FLOAT CONTROL (FLOODED)

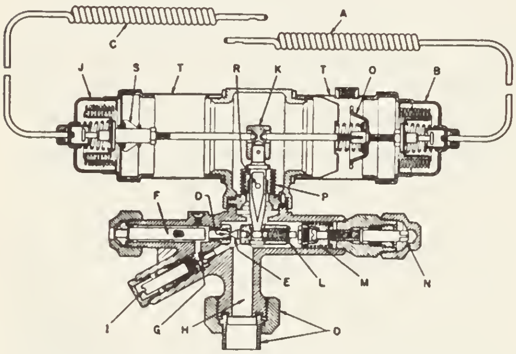
The second and one of the most popular methods of controlling the re-

frigerant flow in the 1920's and 1930's was that used in the flooded system of refrigeration. It consists simply of a float operating in the cooling unit which controls the level of the liquid refrigerant in the cooling unit, Figure 5-38.



5-36. A differential type thermostatic expansion valve. A. Refrigerant inlet; B. Refrigerant outlet; C. Anti-surge adjustment; D. Superheat bulb; E. Cooling coil bulb. (Detroit Controls Corp.)

The float is connected either to a needle valve or a ball check valve and is calibrated so the valve will close when the float is at the proper level;



5-37. Differential temperature expansion valve designed to meet needs of extremely low temperatures. A. Superheat bulb; B. Superheat power element; C. Evaporator bulb; D. Main valve orifice; E. Main valve needle; F. Strainer; G. Bypass valve orifice; H. Outlet passage; I. Bypass valve adjustment; J. Evaporator power element; K. Operating lever; L. Needle carrier assembly; M. "Anti-surge" spring; N. "Anti-surge" adjustment; O. Factory superheat adjustment; P. Sealing bellows; Q. Forged union connection; R. Operating lever fulcrum; S. Anti-chatter device;" T. Stainless steel spacer. (Detroit Controls Corp.)

that is, when there is a certain level of liquid refrigerant in the cooling coil.

The suction tube of these cooling units extends into the float chamber and has its opening located near the top. This opening is protected from picking up liquid refrigerant by having a baffle plate located between it and the liquid. This baffle is necessary because the liquid as it evaporates is sometimes agitated violently. If this baffle plate were not provided, the suction tube might receive liquid refrigerant in it when the compressor is running.

These cooling coils, or boilers, are usually made of copper (tin-dipped). The float chamber has tubes running out of it and down, forming a box for the ice-cube trays; the tubing then returns to the float chamber. The joints are sealed by copper hydrogen brazing or silver brazing although some early types were soft soldered. The float itself is usually a sealed brass ball connected to the needle by means of a brass lever. The needles used in early refrigerators were made of steel but are now made of stainless steel or Stellite. The seats are built into the removable header and are made of brass or Monel metal. Five to seven cap screws hold the header in place. A lead gasket is usually used to seal the joint, because it is easily broken open, it takes up little space, it needs no cleaning upon removal, and it may be used again. The cap screws may be made of either Monel metal or may be cadmium plated steel to prevent rusting.

5-16. LOW PRESSURE FLOAT CONTROL (PAN TYPE)

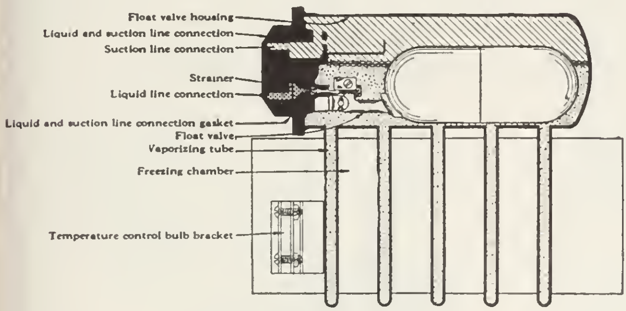
Figure 5-39 illustrates the pan type or bucket type of float. This float is made of brass and operates similar to the ball type. The header on this type of float is usually welded into place and cannot be removed. A removal

cartridge type needle and seat assembly is therefore used. The ball type floats are used with most of the sulphur dioxide units and with the old methyl chloride units. The pan type float is now used with methyl chloride, because it insures a more positive oil return. This return is accomplished by extending the suction line into the bucket, since the oil collects in the open bucket as it settles out of the spray in the float chamber. One company uses a wick to help remove the oil from the chamber into the bucket.

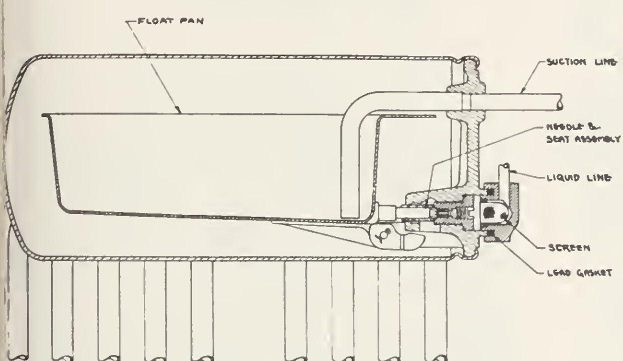
place in the cooling coil; this will oil-bind the refrigerant. If the float is calibrated so the refrigerant level is too high this will result in liquid refrigerant entering the suction line, and a frosted suction line will result. This will increase the cost of operation of the machine.

These floats are adjustable either by bending the float arm or by a special adjusting screw on the mechanism as illustrated in Figure 5-38.

Another feature to be noticed is that the oil in the sulphur dioxide units



5-38. A low-pressure side float control.



5-39. A pan-type float control. (Norge Corp.)

The low side floats must be very carefully adjusted or calibrated when assembled in order to control the liquid level at a certain definite setting in the cooling coil. If the float mechanism is adjusted so the refrigerant level is too low, it will result in a lower than normal low side pressure. Also, if the refrigerant level is too low, an excess accumulation of oil will take

settles on the top of the refrigerant when it collects in the cooling unit, because the oil is lighter than the refrigerant. The float must be designed to allow for a certain oil layer and amount of refrigerant.

It is a peculiar phenomenon of refrigerants that if they are not agitated or helped in some other way, the pressures may sometimes be reduced

far below the refrigerant's boiling point at that temperature before the liquid will start evaporating. This peculiarity is greatly increased by the layer of oil always present on top of the refrigerant, which acts as a choke or retarder.

Many methods have been promoted to prevent this occurrence; these include sawed tubing, tacks, and other materials, which are placed in flooded cooling units. Some of these are still being used, but perhaps the best development along this line has been the use of special wood which, when located in the liquid-filled tubes of the cooling unit, acts as a catalytic agent and makes the refrigerant boil at the correct temperature. These substances are called ebulators.

5-17. LOW PRESSURE SIDE FLOAT CONTROL TROUBLES

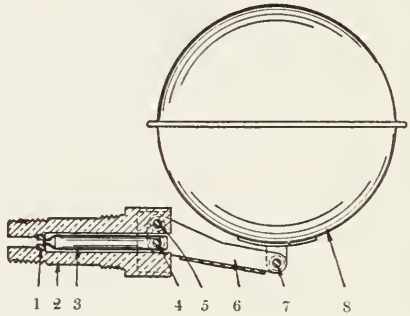
The float control is practically foolproof, but occasionally the unit will stick either open or closed. A closed needle valve may be detected by a lack of refrigeration, a high vacuum on the low pressure side; a leaky needle may be indicated by a continuous gurgling or hissing in the cooling unit after the compressor has stopped, an equalizing of the pressure gauges, and a frosted suction line.

5-18. HIGH PRESSURE SIDE FLOAT CONTROL

Another control that is similar in construction to the low pressure side float control, except that the float is located on the high pressure side of the system, is the high side float valve. This float maintains a constant level of liquid refrigerant on the high pressure side.

As the refrigerant is condensed in its condenser, it flows directly to the high side float chamber (no liquid receiver is used). As the liquid level rises, the float opens a valve allowing refrigerant to flow into the cooling coil.

The floats are made of either copper or steel. In the hermetic or semi-hermetic units the steel type is usually used. These units cannot use a liquid receiver unless the float is located within it. These float controls do not have as much difficulty with oil binding as the low side float control, because at the higher pressure the oil is dissolved more readily in the liquid refrigerant and circulates with it. However, the cooling coil used in connection with a high side float control must



5-40. A high pressure side float refrigerant control.

be equipped with a special oil return, or oil binding trouble will be encountered in it.

The high pressure side float is now preferred to the low side float in that it permits a cooling coil design which utilizes all the coil space for useful refrigeration rather than float chamber space.

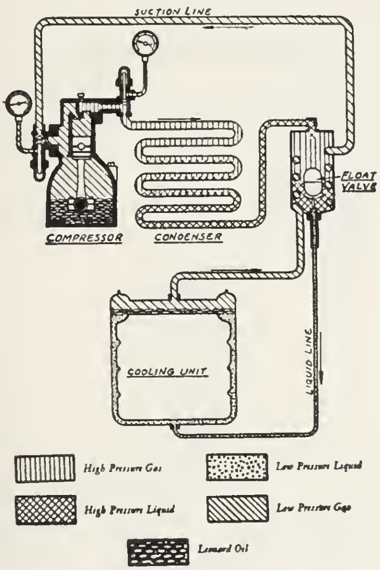
The float must be a sealed ball, and it is connected directly to the needle, or it operates the needle by a simple lever, Figure 5-40. The needles and seats are made of long wearing alloys such as stainless steel or hard surfacing alloys.

Both the copper or steel floats are subject to crushing if the high side pressure becomes excessive. A crush-

ed float will not rise with the liquid level and the cooling coil will be evacuated. A stuck-closed valve also causes an evacuated cooling coil. Tapping briskly on the float chamber may free the valve, or if the float is made of steel, an electro-magnet may be used to raise it.

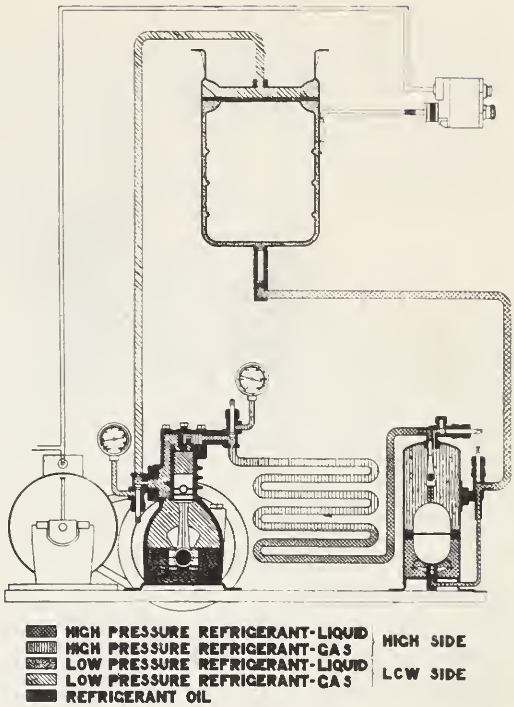
5-19. SPECIAL HIGH PRESSURE FLOAT CONTROL INSTALLATIONS

There have been four principal cycle designs using high side floats. One design has the condensing unit top

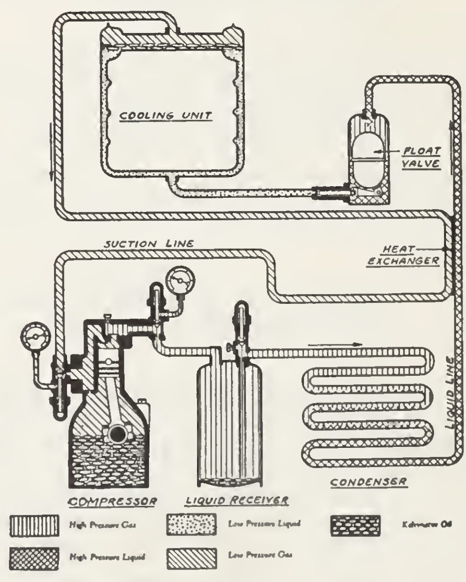


5-41. A top mounted unit with a high side float control.

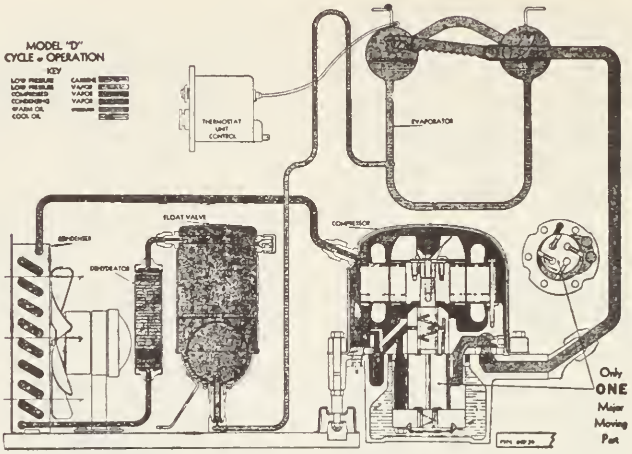
mounted and the float is located near the condensing unit, but the line from the float needle to the cooling coil is all within the cabinet insulation, Figure 5-41. Another design has the float located on the condensing unit, and it uses a weight check valve located near the cooling coil to prevent frosting of the liquid line, Figure 5-42. A third design locates the float in the back wall of the cabinet semi-buried in the insulation, Figure 5-43. The fourth de-



5-42. A base mounted high side float control using a weight check valve. A. Weight valve.

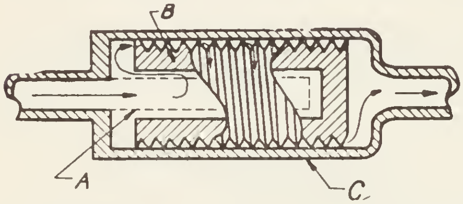


5-43. A refrigerating unit with the high side float located in the back wall of the cabinet.



5-44. A base mounted high side float mechanism. A capillary tube connects the high side float to the cooling coil.

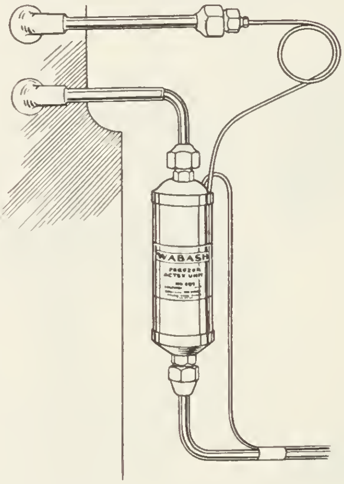
sign uses a high side float located on the condensing unit, and a capillary tube is used to convey the reduced pressure liquid refrigerant to the cooling unit, Figure 5-44. In the three latter designs the refrigerant lines from the high side float to the cooling coil are insulated.



5-45. A refrigerant "Restrictor" which operated similar to a capillary tube refrigerant control. A. Screen, B. Threaded cylinder, C. Housing.

5-20. CAPILLARY OR CHOKE TUBE REFRIGERANT CONTROL

An increasingly popular refrigerant control is the capillary or choke-tube type. This control consists of a very small diameter length of tubing which acts as a constant throttle on the refrigerant. It was first used successfully in the late 1920's with the Rice domestic refrigerator using methyl chloride and is now being used by practically all manufacturers. It is a peculiar control inasmuch as the amount of refrigerant in the system must be very carefully calibrated, as all the liquid refrigerant moves into the low side during the off-cycle. Too much refrigerant will cause the unit to frost back on the low side. It must be used in conjunction with a thermostatic motor control. The Rice machine used a capillary tube 27 inches long, and the diameter was 1/16 inch.



5-46. A capillary tube suction line combination. (Wabash Corp.)

The 1934 and 1935 Frigidaire Standard line used a refrigerant control

similar in action to the capillary tube control. It was called a "Restrictor" and consisted of a refrigerant passage formed by the threaded portion of a large diameter screw tightly enclosed in a housing, Figure 5-45.

5-21. CAPILLARY TUBE DESIGNS

The capillary tube refrigerant control, Figure 5-46, does not have any moving parts; therefore it has several advantages. First, there are no parts to wear or stick; second, the pressures balance in the system when the unit stops. This condition placed a minimum starting load on the motor.

Capillary Tube Diameters, O.D. and I.D.

Outside Diameter	Inside Diameter
.083	.031
.094	.036
.109	.042
.114	.049
.120	.055
.130	.065

5-47. Capillary tube diameters, O.D. and I.D.

There are several theories concerning the principle of operation of the capillary tube. The tube presents a fluid flow resistance, and the pressure decreases as the small liquid flow progresses through the tube until the liquid starts to evaporate in the tube. This gas formation provides a sudden pressure and temperature drop in the last one fourth of the length of the tube. It is cooled to evaporator temperatures, and its pressure is reduced to evaporator pressure. This gas formation in the capillary tube is called "vapor lock." The design of the capillary tube depends on four variables:

1. The tube length
2. The inside diameter
3. The tightness of the tube windings
4. The temperature of the tubing

There are several formulas for calculating capillary tube sizes and length, but the best system seems to be to use the original tube size and then change the windings, temperature, and the length of the tube until it functions correctly.

5-22. CAPILLARY TUBE CAPACITIES

The capillary tube refrigerant control is the simplest of all refrigerant controls. It consists of very accurately made seamless copper tubing. The inner diameter is very accurately controlled to provide sensitive pressure reduction. Some popular capillary tube sizes are shown in Figure 5-47.

The .083 O.D. by .031 I.D. is used in Frigidaire and Crosley units. The .114 O.D. by .049 I.D. tubing is used for the Freon 12 domestic unit and is suitable for average temperatures and frozen food temperatures, dependent on the power of the unit and the use.

Approximate sizes for capillary tube installations are shown in Figure 5-48 for Freon 12.

The capillary tube should be soldered to the suction line for several feet of its length (approximately 4 feet). Any extra capillary tube length should be coiled at the condenser end of the tube. A permanent dryer and a very high quality filter should be installed at the inlet to the capillary tube to prevent clogging.

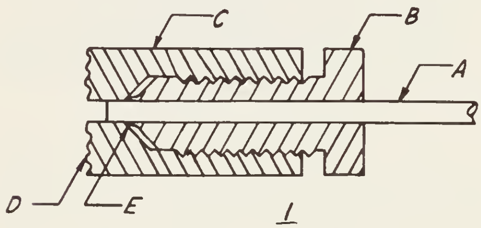
5-23. CAPILLARY TUBE FITTINGS

The capillary tube should be fastened to the cooling coil and condenser or dryer with mechanical fittings that are leak-proof and vibration-proof. Figure 5-49 illustrates two popular ways to make these connections. Part (1) shows the use of a special nut that squeezes against both the capillary tube and the fitting. Because the nose section is deformed as the nut is

Horsepower	Temp.	Capillary Tubing I.D.						
		.031	.036	.040	.042	.049	.055	.065
	H	1.1	2.2	3.5	4.5	9	15	
1/8	M	4	8	13	16	32	56	
	L	9	18	29	36	72	126	
	H						10	
1/5	M	2.2	4.4	7.0	9	18	31	
	L	5.2	10.5	17	21	42	73	
	H						5	
1/4	M	1.1	2.2	3.5	4.5	9	15	
	H							7.5
1/3	M						9.5	
	L	1.75	3.5	5.6	7	14	2.5	

5-48. Standard capillary tube lengths, for typical applications. H is high temperature; M is medium; and L is low. The length of the tube is indicated in feet for each capillary tube diameter.

tightened, the nut should always be replaced when the capillary tube is serviced. Part (2) shows the capillary tube silver brazed to a 1/4 O.D. soft copper tubing. The larger tube may then be connected to the system by the usual flared fitting. Part (3) shows a larger tube soldered to the capillary tube and



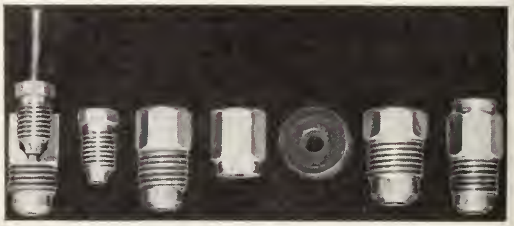
5-49. Capillary tube connections. A. Capillary tube; B. Special compression nut; C. Connector fitting; D. This fitting attached to the refrigerator mechanism wtih either threaded or silver brazed connections; E. Compression nose seal against tube and fitting; F. 1/4 in. tubing; G. Flare nut; H. Connector fitting; J. Silver brazed; K. Swedged tube to capillary tube and silver brazed.

the larger tube attachment made with a connection flared fitting, Figure 5-50.

In some cases the capillary tube may be found soldered into the system. However, mechanical connections may be substituted at the time of overhaul.

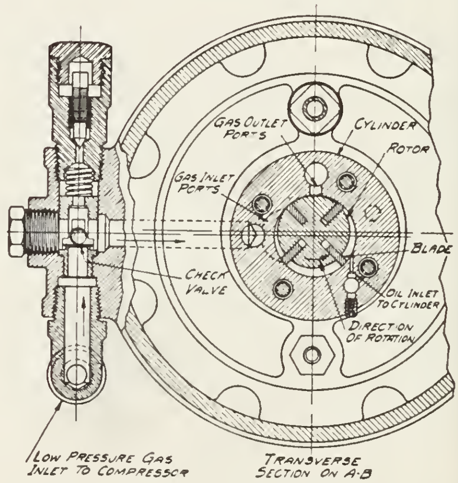
5-24. CHECK VALVES

Rotary and gear compressors are equipped with check valves in the suc-



5-50. Capillary tubing connections. (Wabash Corp.)

tion line to prevent backing-up of the high pressure gas and the refrigerant oil into the cooling unit, Figure 5-51. These check valves may use either a disc or a solid ball in their construc-



5-51. A low pressure side check valve.

tion. They may also operate differently; some use a spring to keep the valve against the seat; others are mounted so the weight of the valve keeps it against its seat.

5-25. SOLENOID VALVES

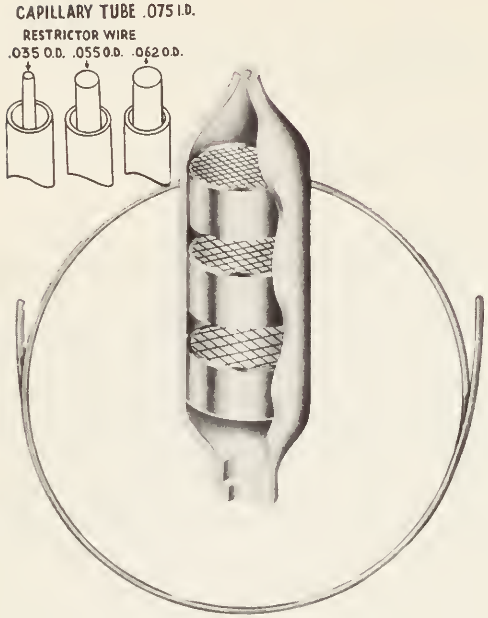
A valve that can open or close refrigerant lines by using electricity is often used in refrigerating systems. It is an electro-magnet with a movable core or center. If the movable center is a valve stem, an electric switch can be used to close the refrigerant line. Some domestic refrigerators use this valve, but it is very popular in commercial refrigeration. A detailed explanation of its operation will be found in Chapter 19.

5-26. SUCTION PRESSURE VALVES

Many systems use bellows or diaphragm-operated pressure regulating valves on the low side of the system. Some operate from the cooling coil pressure and therefore keep the pressure in the cooling coil constant. Some operate from the crankcase pressure and therefore keep the compressor from being overloaded. These valves may be studied in Chapter 19.

5-27. REVIEW QUESTIONS

1. What is meant by float calibration?
2. How many pressures or forces influence the needle movement of an automatic expansion valve needle.?
3. Why are expansion valves made adjustable?
4. Which refrigerant controls can operate satisfactorily with a varying amount of refrigerant in the system?
5. What is thermostatic expansion valve superheat?
6. How much liquid refrigerant turns into gas as the refrigerant passes by the needle valve?
7. What is the thermal bulb charge in thermostatic expansion valve?
8. What mesh screens are used in refrigerant controls?
9. When was the thermostatic expansion valve first used?
10. What is the most common expansion valve body material?
11. What may happen if the thermostatic expansion valve orifice is too large?
12. How does the liquid line fasten to the expansion valve?
13. Why does the suction line extend down into the pan type float?
14. What is a cartridge needle?
15. How may low side floats be adjusted?
16. Of what materials are high side floats made?
17. What causes a high side float to collapse?
18. What is done to permit locating the high side float in the base of the cabinet?
19. What is the purpose of an automatic refrigerant control?
20. How does a capillary tube operate?
21. Does a capillary tube system have a liquid receiver?
22. What happens to the capacity of a capillary tube if the tube is lengthened?
23. Does a capillary tube need a filter or a screen at its inlet?
24. Is it possible to adjust the capacity of a capillary tube?
25. What type of system needs a check valve?



5-52. An adjustable capillary tube for service work. This design enables one unit to be adjusted to all temperature applications, most capacities and for either refrigerant 12, or 22.
(Watsco, Inc.)

5-28. CAPILLARY TUBE FOR SERVICING UNITS

A clever capillary tube system which is easily adjusted and installed for any system of low, medium, or high temperature using either refrigerant 12 or 22 is shown in Fig. 5-52. The tubing is of the same O.D. and I.D. for all systems, but the capacity is varied by putting various diameter wires of various lengths inside the tubing. A complete table of wire sizes and lengths to use is furnished with each unit.

Chapter 6

MOTOR CONTROLS

The purpose of automatic refrigeration is to provide correct refrigerating temperatures with a minimum of attention. To produce these temperatures under a variety of conditions, it is necessary to use a refrigerating unit with more capacity than is ordinarily needed. Therefore, this unit would over refrigerate under continuous operating conditions.

There are two possible ways to stop heat removal when a satisfactory temperature has been reached:

1. The most popular way is to stop the motor when the correct temperature is reached.

2. The second method is to stop and start the flow of refrigerant in the system when the correct temperature is reached. This latter system is frequently used in multiple commercial systems but very seldom in single units.

The motor controls for hermetic systems are more involved then those used for open or conventional systems. The hermetic system uses a starting relay and as many as three safety devices in the electrical circuit. The modern hermetic also incorporates automatic defrosting in many units.

6-1. REFRIGERATION ELECTRIC MOTOR CONTROLS

The temperature inside the cabinet should be maintained within certain limits; therefore, the machine must shut off (cutout) when the low limit of temperature is reached, or food will spoil by slow freezing; likewise, when the cabinet temperature rises again, the machine must start (cut-in).

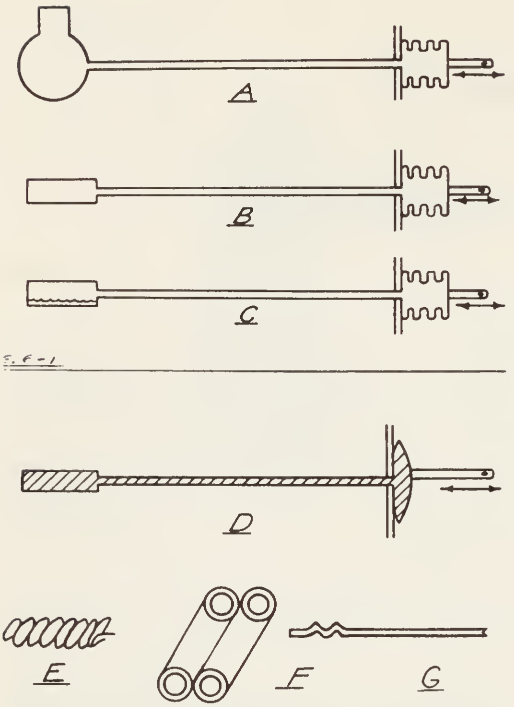
To actuate the cut-in and cut-out, two types of motor controls are used, the pressure type and the thermostatic type.

This chapter discusses the thermostatic type extensively as it is the one used in domestic refrigeration. The pressure type is used extensively in commercial refrigeration, and its operation is discussed in detail in Chapter 19.

The running time naturally varies depending on the room temperature, the frequency of use of the refrigerator, and the size of the refrigerating unit. For the Northern states, the running time is approximately 35 to 40 per cent of the time; for the Southern states, the running time may become approximately 50 per cent of the time for most refrigerators.

In the older designs, the unit would cycle over a two to three-hour period. That is, the running time and off time of the mechanism would total between two and three hours. The recent trend has been to decrease the over all cycling time so that now refrigerators may run 5 to 10 minutes and be off 10 to 20 minutes.

Also, it is a standard practice among the manufacturers to design their units so the electric motor operates a total of only 8 to 14 hours out of the 24, which is approximately 40 per cent of the time.



6-1. Methods used to obtain motion from temperature and pressure changes. A. Low side pressure bellows; B. Gas charged temperature response bellows; C. Vapor pressure temperature response bellows; D. Liquid charge temperature response diaphragm; E. Some bulbs capillary tube coil used as a bulb; F. Enlarged view of E sensitive element; G. A capillary tube used as a bulb.

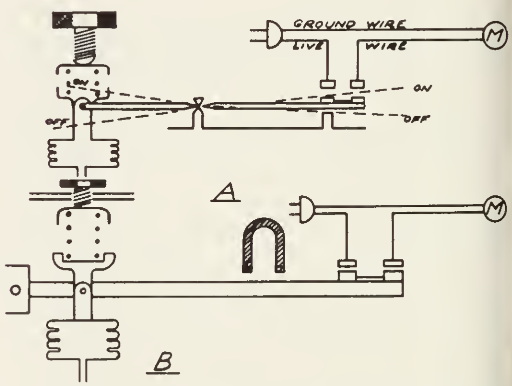
This fourteen-hour operating time is on the basis of standard use of the cabinet. If the cabinet is used more, the running time will be longer. If the usage is less, the running time is less. The average cabinet runs far below 14 hours of the 24. The usual time is from 8 to 10 hours of the 24.

6-2. MOTOR CONTROL PRINCIPLES

Any device which will change its position as the temperature varies or as the pressure varies, can be used as a motor control device. A piece of metal that expands as temperatures rise and vice versa could be used. This movement can be easily connected to a switch. This type is too slow, however, and its movement is so small that it is not used in refrigeration.

A bi-metal strip is also used to produce motion as the temperature changes. It is used where very small differentials are desired, such as in a house heating thermostat.

By using a bellows or diaphragm, pressure changes can come from either a confined fluid or from the low pressure side of the system. This system is the one most used, Figure 6-1. As the pressures rise in the low side or in the sensitive bulb due to a temperature rise, the pressure will rise in the bellows or diaphragm, and the bellows will move to the right against atmospheric pressure and any spring pressure present. This movement, when connected to a snap-action switch will cause the switch to snap closed, and current will flow to the motor. When the pressures and temperatures decrease, the bellows or diaphragm will tend to collapse, and the toggle or snap switch will be pulled into the open position, Figure 6-2.



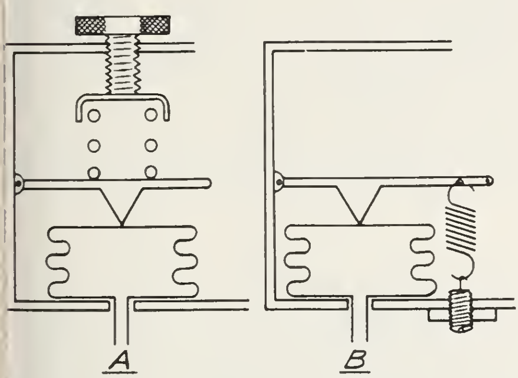
6-2. Methods of connecting a bellows to a snap action switch. A. A toggle snap action for motor controls; B. A magnet snap action for motor controls.

The motor control performs two functions: (1) it maintains certain temperature limits within the cabinet, and (2) it controls the cycling time of the refrigerating unit. To obtain these two conditions, two different adjustments

are used: (1) a range adjustment, the purpose of which is to make the box colder or warmer; (2) a differential adjustment, the purpose of which is to adjust and regulate the running time cycle of the unit. The knob that is located to permit the user of the refrigerator to adjust the temperature, is a range adjustment. The differential adjustment is generally located so that only the serviceman can change the cycling interval.

6-3. RANGE ADJUSTMENT

A sample of a range adjustment is as follows: if the unit cuts-in at 25 F. and cuts-out at 15 F. cooling unit temperature, the range is the value of the two. To make the box operate at a



6-3. Adjusting the range settings of a motor control. A. A compression spring range adjustment; B. A tension spring range adjustment.

warmer temperature, the range adjustment is adjusted so the cut-out becomes 16 F. and the cut-in 26 F. Note that the temperatures are higher, but the distance between the two has not been changed. This condition will only slightly affect the running time of the unit due to the fact that the box is not as cold now, and therefore, the condensing unit will not have to do quite so much work.

6-4. RANGE ADJUSTMENT MECHANISMS

The range adjustment is easily recognized by the fact that it is an adjustable force pressing directly upon the bellows or diaphragm which operates the switch; this force is always being exerted upon the bellows whether the switch is in the cut-out position or in the cut-in position.

The adjustable force may be either an adjustable weight that always presses against the bellows, or, more commonly, it is a spiral spring with an adjustable screw which either changes the pressure or the tension of the spring.

The spring may press or pull either directly on the bellows or diaphragm or on a lever that is attached to the bellows, Figure 6-3.

Most of the range adjusting screws have a calibrated dial, or have a pointer connected to the screw that indicates the direction they should be turned for a warmer setting or colder setting and the temperature of this setting.

6-5. DIFFERENTIAL ADJUSTMENT

The differential adjustment sets the temperature difference between the cut-out and cut-in temperatures. If the cooling coil is set to cut-in at 25 F. and cut-out at 15 F., the difference or differential is 10 F. To cycle the machine more frequently, one could change the distance between the two settings as follows:

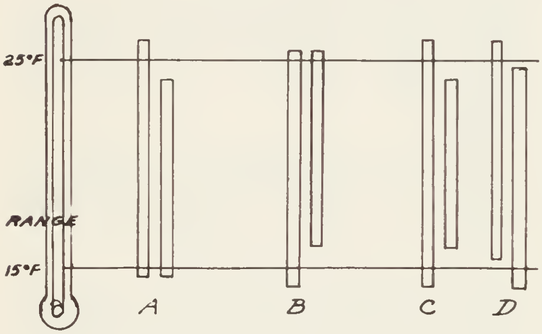
1. 15 F. - 24 F. (cut-in only)
2. 16 F. - 25 F. (cut-out only)
3. 16 F. - 24 F. (both cut-in and cut-out)

Note that whenever the differential (the distance between the settings) is changed, the range is also changed, but if the range is adjusted the differential

is not necessarily affected, Figure 6-4.

If the unit turns off and on too frequently and maintains a very good steady cabinet temperature, the differential may be increased to allow less frequent starting of the motor by increasing the differential, for example, from 10 F. to 11 F.

Referring to Fig. 6-4, the differential is adjusted in three ways: (A) the cut-in point may be moved without changing the cut-out, (B) the cut-out point may be moved without changing

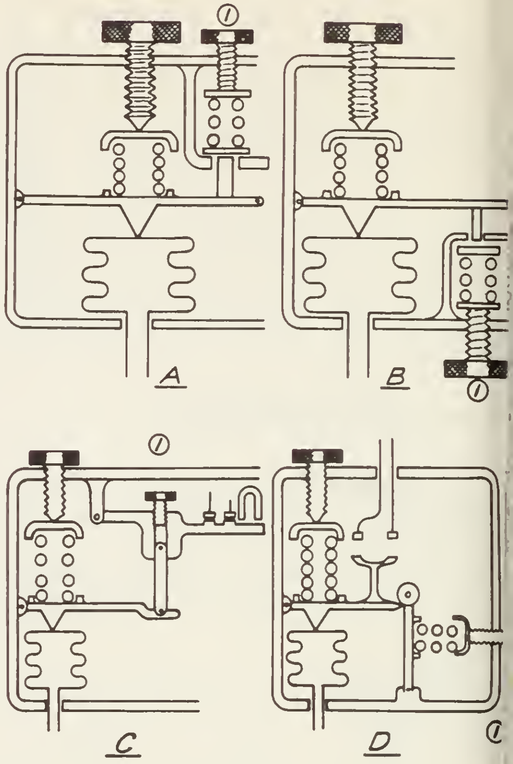


6-4. Effect of different control adjustments. A. Cut-in setting lowered; B. Cut-out setting raised; C. Cut-in lowered and cut-out raised; D. Range adjustment cut-in lowered and cut-out lowered.

the cut-in, (C) they both may be adjusted farther apart or brought closer together. One will usually find one of these three different types of differential adjustments built into a control.

An example of (A) is to change the 15 F. and 25 F. adjustment to 14 F. and 25 F. One may first turn the range adjustment to 14 F. and 24 F.; then change the cut-in differential to 25 F. producing a new setting of 14 F. and 25 F. Another way would be to adjust the differential to 15 F. and 26 F., and then change the range to 14 F. and 25 F.

Note that this will make the cabinet become colder before it will cut-out, but by simply adjusting the range adjustment to $14\frac{1}{2}$ F. and $25\frac{1}{2}$ F. after the differential has been increased, one will



6-5. Various types of differential adjustment mechar isms. A. Cut-in type; B. Cut-out type; C. Cut-in typ using a slot and magnet; D. Double type.

get almost the same results as in th first setting.

An example of (B) is to change 15 F and 25 F. to 15 F. and 26 F. One ma first change the range from 15 F. ar 25 F. to 16 F. and 26 F., then chang the cut-out differential from 16 F. ar 26 F. to 15 F. and 26 F. Or, one ma adjust the cut-out first and then chang the range.

An example of (C) is to change 15 F and 25 F. to 13 F. and 25 F. One ma first change the differential from 15 F and 25 F. to 14 F. and 16 F., the change the range from 14 F. and 26 F to 13 F. and 25 F.

A differential adjustment of the firs two types may be recognized by the fac that it affects the operation of th switch mechanism; in the first cas

only when the switch is in the cut-out position or in the second case, only when the switch is in the cut-in position. The third type differential adjustment, which is very common, is usually an adjustable arrangement which affects the effort of the toggle to snap off and on. (D) shows the effect of the range adjustment. A range adjustment affects both the cut-in and the cut-out.

6-6. DIFFERENTIAL ADJUSTMENT MECHANISMS

Two types of differential adjustments have a spring that affects the movement of the bellows either just before it cuts-out or cuts-in, but not both. This limited action is obtained by using a stop on the spring, Figure 6-5.

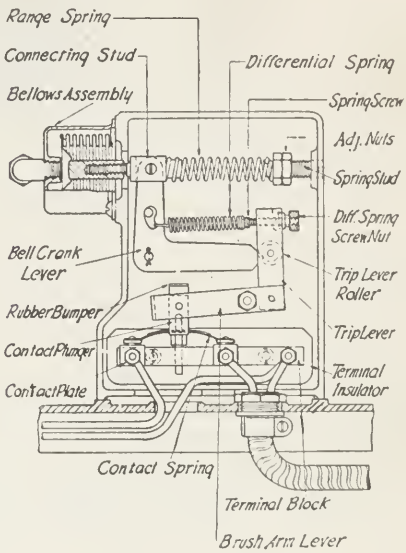
The third type of differential adjustment affects both the cut-out and cut-in by using a spring or a magnet to make it easier for the points to open and close, or more difficult for the control to open or close the electrical contact points.

6-7. PRESSURE CONTROL

To have any refrigeration effect at all in the box, a low pressure must be maintained in the cooling unit to permit evaporation of the refrigerant at a low temperature. Therefore, one automatic control of the motor is based on pressure differences in the cooling unit. This is the old style domestic control and is now used only on commercial systems.

It operates as follows: when the pressure builds up in the cooling unit, a bellow expands, a switch is automatically thrown, and the motor starts; then when the pressure becomes low enough, the bellows contract and the motor is automatically shut off.

The electrical switch is of either the mercury bulb or of the open contact point type, using a bellows-actuated toggle, Figure 6-6. As may be seen from the drawing, a pressure rise in the bellows chamber will rotate the bell crank lever clockwise and allow the trip roller to roll up the incline on the end of the lever, causing the contact points to lower and touch the fixed electrodes. As soon as the motor-

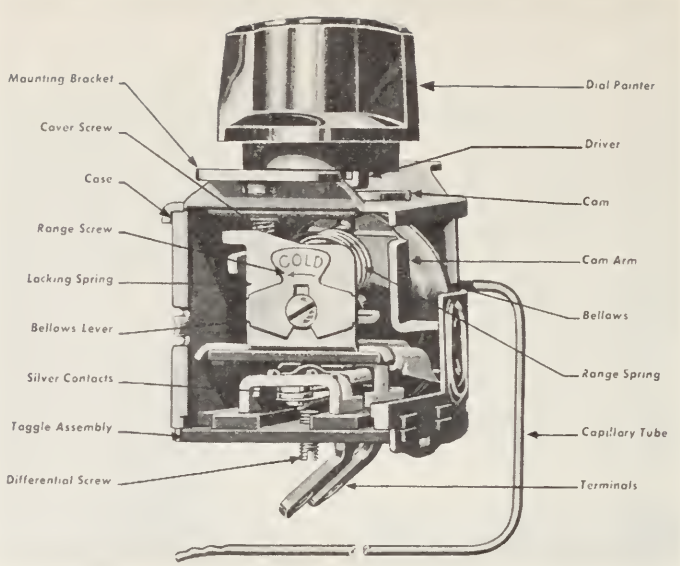


6-6. A low pressure operated motor control.

operated compressor reduces the pressure, the bell crank reverses its motion, causing the roller to roll down the incline after it has rolled over the point pulling the contacts up and opening the circuit.

The range adjustment will lower the cut-in and cut-out an equal distance if the nuts are moved out (contra-clockwise), and will raise the cut-in and cut-out pressure if turned in (clockwise).

The differential adjustment separates the cut-in and cut-out pressure when turned farther to the right (clockwise) or vice versa. This is the double type differential adjustment. If the spring tension is increased by turning the nut clockwise, it is harder for the bell crank lever to move over the roller, no matter in what direction it is



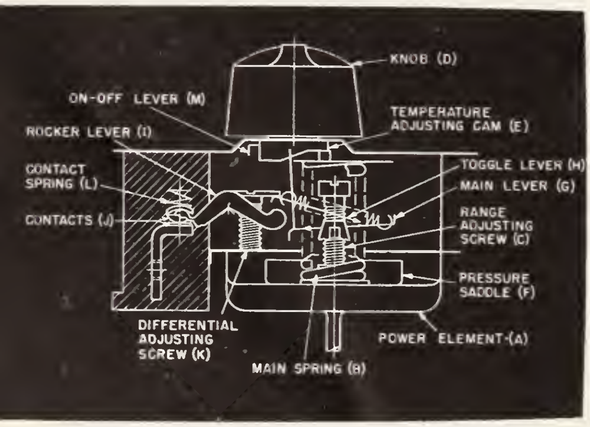
6-7. A remote power element thermostatic motor control. This control is used in household units and small commercial units. It has a cut-in type differential.
(Ranco, Inc.)

moving. This naturally increases the pressure difference between both the cut-in and cut-out points.

Some models of this particular control are also equipped with a safety control. It is of the bellows construction with a pressure tap to the high pressure side of the compressor so that, if the compression pressure or head pressure should be too high, this bellows would throw the switch out of contact, stopping the motor. This is only a safety device for the motor. It is especially necessary when a water-cooled unit is used. See Chapter 19.

The low pressure type of control is of such a nature that it is easy to adjust while on the job. It can also easily be adjusted with a vacuum pump and a compound gauge after it has been removed from the unit.

The adjustment of these controls is very important, because lasting satisfactory operation of the unit depends to a great extent on their accuracy.



6-8. A late model motor control. Note the single dial control knob, the range adjustment and the differential adjustment.
(Cutler Hammer Inc.)

6-8. THERMOSTATIC MOTOR CONTROLS

Thermostatic motor controls may be classified into three types according to their internal construction and operation. These types are:

1. Self-contained type
2. Remote power element type
3. Double remote power element type

6-9. REMOTE POWER ELEMENT TYPE CONTROL

The type of temperature control now in use uses the same basic principles as above, but in addition it may be equipped with safety devices and a defrosting switch. Its design is also different in this respect: it has a remote power element which is connected to a bellows in the electrical control by means of a capillary tube, but its operation is identical. That is, as the power element warms, its pressure operates upon a flexible bellows or diaphragm, located in the rear of the temperature control. This bellows presses against an arm under spring tension; and when the pressure becomes high enough, it throws two silver contacts together completing the electrical circuit and starting the motor.

The thermostatic control using a remote power element is now used in the majority of refrigerators of conventional design, Figure 6-7. The thermostatic control using two remote power elements is used on many units equipped for automatic defrosting.

Special devices, such as over load cut-out, automatic defrosting, manual switch, and range adjustments, which provide control of cooling coil temperatures, are incorporated in many of the thermostatic motor controls. A modern termperature control is shown in Figure 6-8.

After the cooling unit has become cold enough, the power element will cool; the resultant drop in pressure will cause a contraction of the bellows which in turn allows the spring pressure to make the silver contacts fly apart. These silver contacts are built into a lever toggle system controlled by springs so that when they are opened and closed, they do it very rapidly with a snapping action. They are designed this way to reduce the arcing at the points.

The adjustment of this temperature control consists merely in turning the knob in the direction specified on the cold control; that is, increasing the large spring pressure will make the unit warmer, and releasing the spring pressure will make the unit colder.

To increase or decrease the temperature difference or differential between the cut-in and cut-out points, a small screw is located in the bottom of the case. The more the small screw is turned in, the less the differential, and the more the small screw is turned out (contra-clockwise) the more the differential.

The differential screw adjusts the distance the arm can move in the open position. By turning the screw in, the cut-in temperature can be raised or vice versa. However, this screw has no effect on the cut-out, as the lever is away from the screw in the points closed position. This differential is not to be touched, however, unless absolutely necessary.

6-10. DEFROSTING SWITCH, SAFETY OVERLOAD

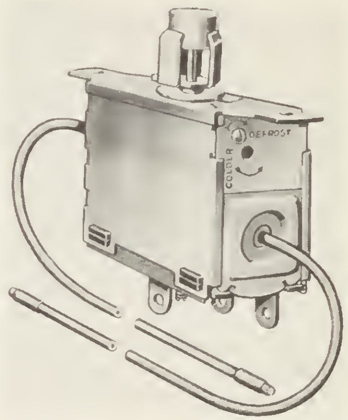
The operation of the original manual defrosting switches is as follows: to the defrosting switch button is fastened a long arm; when pulled out, this arm has a little catch on it which holds the silver contacts apart until the control button is pushed back again.

A small ratchet rack and gear attachment are incorporated in a safety fuse or time fuse and operate as follows: directly in series with the wires going to the silver contact points is a heating coil which is wrapped around a shaft holding the ratchet gear. This coil is so designed that if the motor runs too long or draws too much current, it will get so warm that it heats the solder holding the ratchet gear to the ratchet axle; when the solder gets hot enough, it will melt, freeing the ratchet gear.

The ratchet rack has a spring tension on it and when released it pulls the rack up. This rack has a shoulder which catches the silver electrode lever, breaking the circuit. That is, as soon as the solder melts, this arm will move up, pulling the defrosting button out and shutting off the electric motor. Naturally, as soon as the circuit is cut, the heating coil ceases to work, being in series with the rest of the electrical line, and the solder will resolidify so that when the housewife pushes the button back in, the outfit will work as before. This particular design was practically universal in the domestic models during the 1930's; for that reason its operation and adjustment should be very well understood.

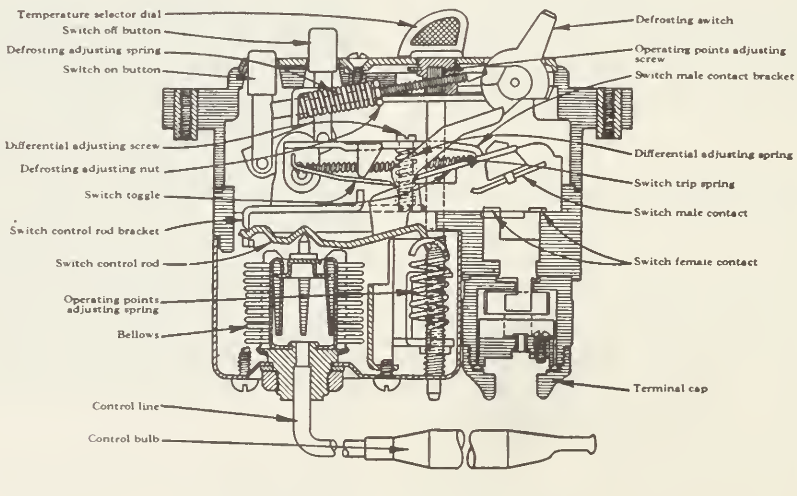
6-11. SEMI-AUTOMATIC DEFROSTING CONTROLS

During the late thirties, various devices were introduced incorporating semi-automatic defrosting. The devices were made to do the following: (1) defrost the unit, when the housewife presses the button, and then return to ordinary operation automatically. The housewife has only to start the defrosting; the rest is automatic. (2) Raise the range fixed definite amount by pressing a button. With this action, the cooling coil will run at a warm enough temperature to permit defrosting, but will still

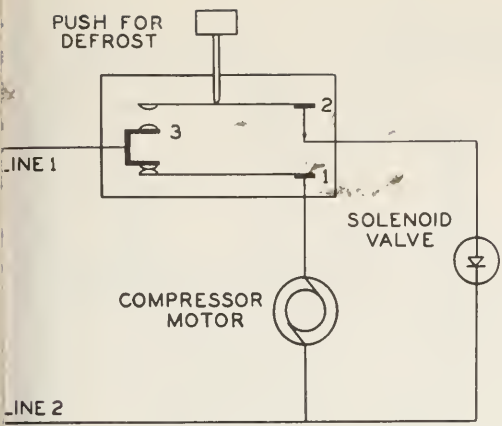


6-10. A combination temperature control and defrost control. The defrost range adjustment and the temperature control range adjustment are shown on the case. (Ranco, Inc.)

give satisfactory refrigeration. (3) A third system incorporates a clock arrangement that will automatically (by time) start the defrosting and return the control to normal operation auto-



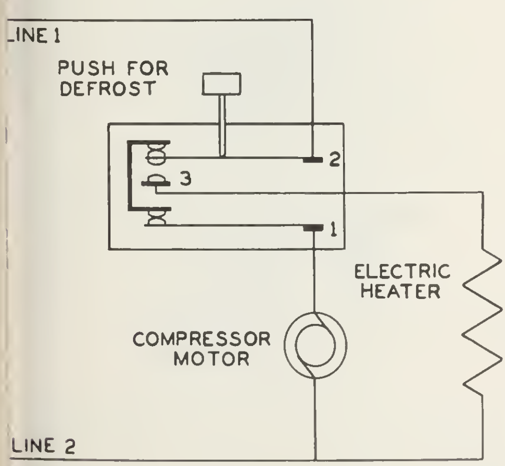
6-9. A semi-automatic defrosting motor cotrol. (Kelvinator Div., American Motors Corp.)



-11. The wiring diagram for hot gas defrosting using the combination control.

natically. This latter type usually perates once every 24 hours. It is ully automatic.

A sample of the manual defrost is hown in Figure 6-9. The range adjustment is the long screw with a moving ut. This nut is fastened to the switch ontrol rod by means of the operating oints adjusting spring. This spring is a ension spring. The differential adjustment controls the distance the toggle is llowed to snap open; therefore, it adusts the cut-in point.



-12. The wiring diagram for an electric heater defrost system using a combination control. (Ranco, Inc.)

The defrosting switch when turned to the left in the figure, puts a load (spring) on the lever extending from the lever that the bellows presses against. Therefore, the bellows pressure must be higher (meaning a higher temperature) to make the contact points snap closed. When the lever does move the defrost switch knob, it returns this knob to its normal operation setting (to the right).

The present day refrigerators which use manual defrost frequently use a double capillary tube control, Figure 6-10. This control uses a power element for normal cycling and the other is a cut-in control for the defrost. The defrosting is started by the housewife pushing the control knob in. This movement opens the motor circuit and closes the circuit to either a defrost solenoid (hot gas) or electric heater elements.

When the coils are defrosted, the defrost capillary tube will create enough bellows pressure to open the defrost circuit and return the control connections to the motor circuit.

A wiring diagram of the control connected to a hot gas defrost system is shown in Figure 6-11. The connections used for an electric defrost system are shown in Figure 6-12.

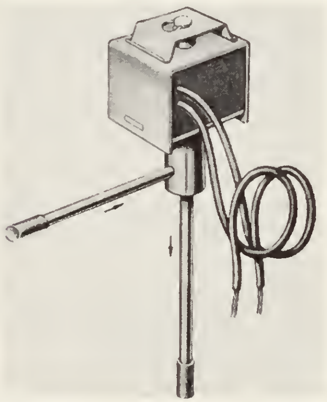
The hot gas method of defrosting uses a solenoid valve to open and close the by-pass from the compressor discharge to the cooling coil. Figure 6-13 shows the valve equipped with connector lines. This valve is similar to the solenoid valves used to control refrigerant flow in secondary systems of two-temperature refrigerators. This valve must be mounted in a vertical position to function correctly. Figure 6-14 shows the solenoid valve installed in a hot gas defrost system, while Figure 6-15 shows it installed in a secondary refrigeration system.

Some refrigerators use two separate controls. One control is the regular thermostat while the other control is the manual defrost control. Figure 6-16

illustrates such a specialized control. It can be used with either the hot gas or electric defrost systems. The control is designed to prevent the defrost cycle from starting if the bellows loses its charge.

6-12. FULL AUTOMATIC DEFROST CONTROLS

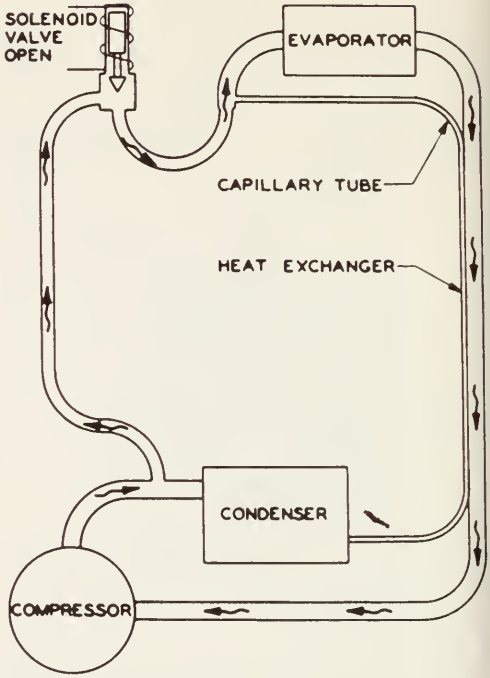
There is a considerable number of refrigerators that have a standard temperature position to the cabinet and a



6-13. A solenoid valve used with thermostats for either hot gas defrosting or secondary system control. (Ranco, Inc.)

frozen foods section. These two purpose cabinets have necessitated a new series of motor controls. First, controls had to be developed that would give correct temperatures in both sections. Second, these controls were also developed to produce complete automatic defrost conditions.

Several different types of controls have been developed. Frozen foods compartments were first used in domestic refrigerators during the late 30's. However, these units used a motor control operated only by the frozen foods coil and overflow from this coil refrigerated the standard section of the cabinet. One company solved the problem by using two separate refrigerating units, each with a motor control. A



6-14. A hot gas defrost system using a solenoid valve. The valve is open and the hot gas is passing directly from the compressor to cooling coil. (Ranco, Inc.)

modern motor control is shown in Figures 6-17 and 6-18.

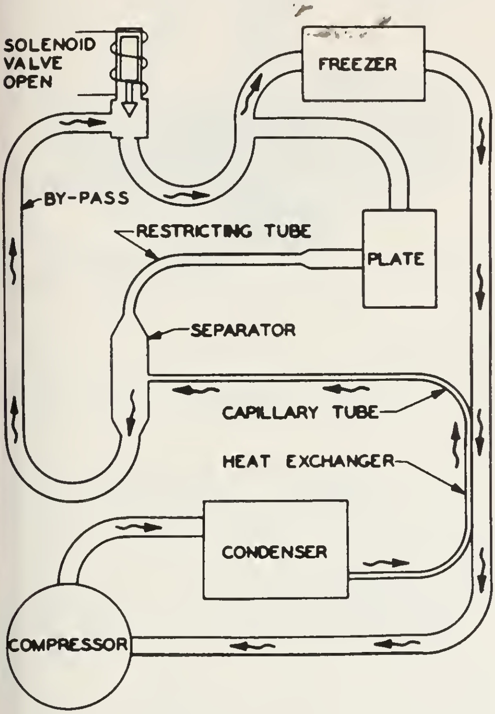
The automatic defrosting mechanism is operated on three different basic means to determine defrosting time.

1. An electric clock which defrosts the unit at certain time intervals.
2. A device which defrosts the unit based on the number of times the refrigerator is opened.
3. A clock which runs only when the unit is running, and which defrosts the unit after several hours of accumulated running time.

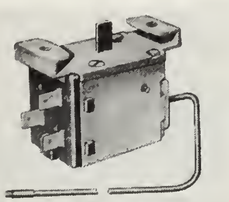
6-13. DEFROSTING CLOCKS

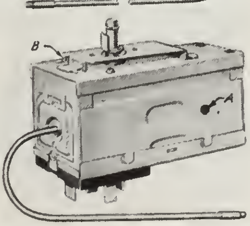
To ease the burden of the housewife and to permit more efficient operation of the refrigerating unit, several companies now have defrosting clocks as standard equipment on their domestic

refrigerators. One of the first refrigerators to use this device was the Sparton refrigerator of 1933 through 1935. The clock is of the self-starting electric type that is connected permanently



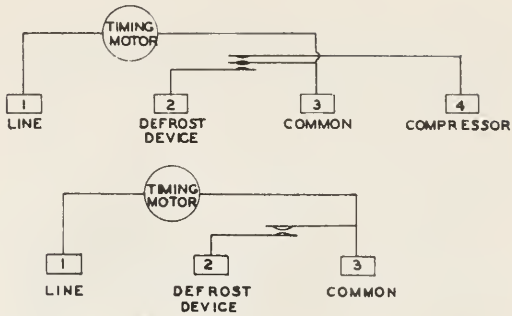
6-15. A secondary system using a solenoid valve to control the temperature in the plate by by-passing the plate on temperature drop.
(Ranco, Inc.)





6-16. A separate defrost control that is used in addition to the regular thermostat.

6-17. A full automatic defrost control. A. Electric motor inspection hole. B. Range adjustment.
(Ranco, Inc.)



6-18. The wiring diagram of an automatic defrost. The top illustration is for an electric defrost system (the motor circuit is broken during the defrost time). The bottom diagram is for hot gas defrost (the compressor continues to run).
(Ranco, Inc.)

across the plug connections. The clock opens contact points in the thermostat circuit for approximately two hours, usually starting at midnight.

In addition to these refrigerators with built-in defrosting clocks, clocks are available for any make refrigerator. They are installed by plugging them into the power outlet and then connecting the refrigerator extension cord into the clock. Figure 6-19.

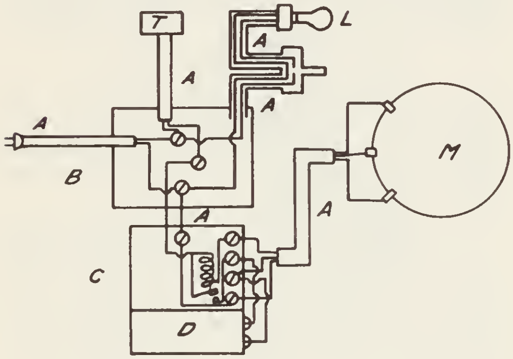
Cabinets with frozen foods compartments will collect excessive amounts of ice and frost on the low temperature coil, and manufacturers have developed means to defrost these coils

6-19. A defrosting clock that can be connected to the power circuit of any domestic refrigerator. The clock is a 24 hour unit and the defrost interval is adjusted on the right.
(Paragon Electric Co.)

quickly without warming the food. Hot gas defrost systems and electrical heating elements are the two basic means used.

6-14. THE WIRING

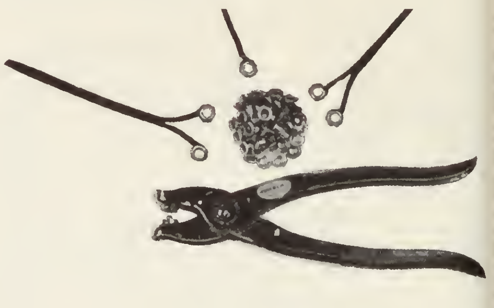
Figure 6-20 is the complete external electrical circuit of a hermetic refrigerating mechanism without a condenser fan motor. The wire is stranded, usually of No. 14 wire size, and is



6-20. A wiring diagram of the external circuit of a hermetic refrigerating mechanism without a fan motor. A. Two wire extension cord; B. Junction box; C. Relay; D. Capacitator; L. Light; T. Thermostat; M. Motor. (AIRSERCO Mfg. Co.)

rubber insulated. The extension cord must be tightly fastened to the plug. The other end of the cord is connected to mechanical terminals in the junction box. Frequently this junction box is part of the starting relay or is under the same metal or plastic cover. The wires are usually fastened to brass terminals moulded in plastic, and small brass screws of 10-32 or 8-32 threads are used to hold them tight. These connections must be tight, or they will cause too much voltage drop (resistance). Some terminals are of the spring clip type.

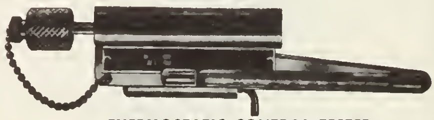
When these relay covers or junction box covers are opened, there seems at first to be an endless number of wires connected to the junction terminals. But when it is remembered that the power source, the thermostat, and the interior light each have two leads, while the motor has three leads, the number of wires is understandable.



6-21. An electrical wire terminal replacement set (pliers and clips).

The most important feature is to determine whether or not the full voltage pressure is reaching the motor. This is done by placing a voltmeter across the leads of the motor.

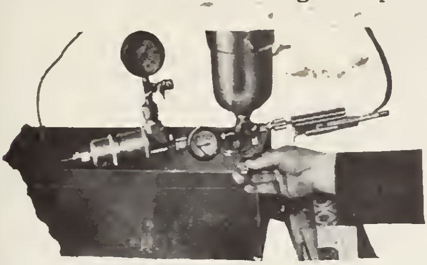
The wires usually have soldered or clamped terminals. These terminals must be in good condition. A very handy tool is a screwdriver with an external or internal clamp so that the screwdriver can be used for both holding the screw as it is being started in the threaded hole, or as it is being removed from the hole. Just wrapping



6-22. A thermostatic testing unit. The refrigerant cylinder connects to the knurled nut on the left. The control thermal bulb fastens to the tester just back of the mercury bulb of the horizontal thermometer.

loose ends of stranded wire around these screws to make a connection is an inefficient and an unsafe practice. Such connections work loose and loose strands sometimes short other termin-

als. It has been proved that old wire loses some of its conductivity, and the insulation loses its qualities. It is recommended that old wiring be replaced.



-23. A thermostatic testing unit being used to test a thermostatic expansion valve.

Wire terminals that may be put on with pair of pliers are on the market. Figure 6-21.

6-15. THERMOSTAT TESTING

A method of checking and adjusting thermostat is shown in Figure 6-22. It consists of a clamp for the thermostat bulb, a very accurate thermometer, and a small cavity for refrigerant. With this instrument mounted on the thermostat bulb and the cavity charged with liquid Freon 12, the little screw for adjusting the boiling pressure, and therefore the temperature of the Freon 12, the bulb temperature can be quickly and accurately lowered and raised to ascertain the adjustment of the control and to readjust it if necessary. Figure 6-23.

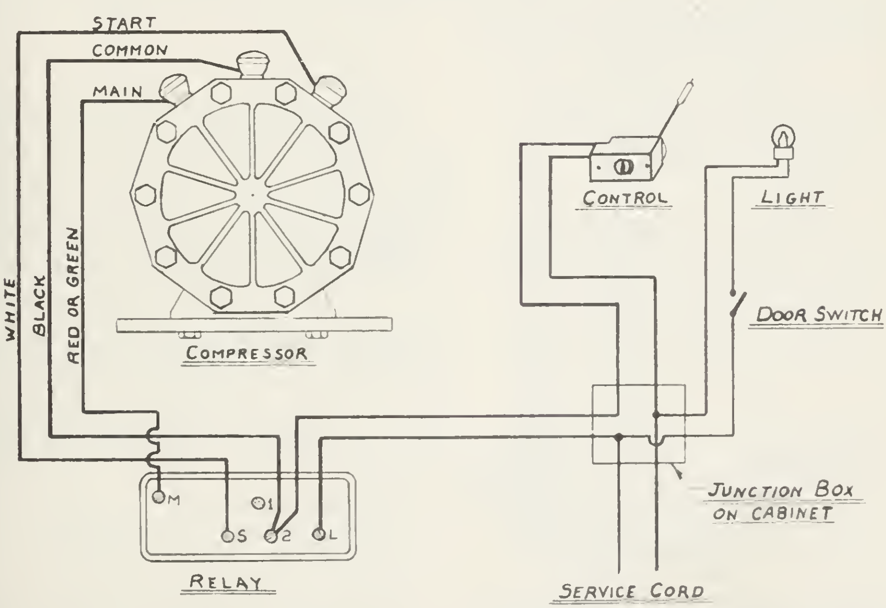
6-16. ELECTRICAL CIRCUITS

The electrical circuits of the late model refrigerators are very similar to one another. The main portions of the electrical system are:

a. Motor
b. Motor control
c. Starting switch
d. Cabinet light and switch

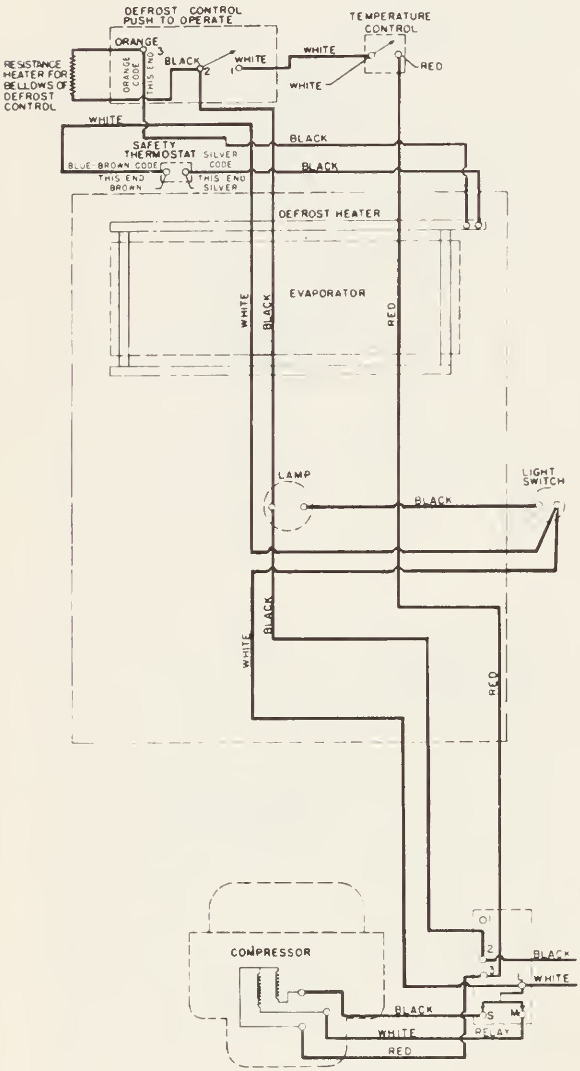
Two other devices used quite frequently are:

a. Condenser motor fan
b. Ultra-violet ray lamp



-24. A complete electrical circuit of a hermetic domestic refrigeration system. This wiring diagram shows a compressor, relay, motor control, light and door operated switch. This is a split-phase system. (Copeland Refrigeration Corp.)

The power is obtained through a rubber covered extension cord usually of No. 14 stranded wire. This cord is connected to a junction box mounted on the condensing unit. This junction box also often houses the starting relay. A three wire cord extends from the junction box to the refrigerator cabinet. These three wires (white, black and red or green) are used for the cabinet light and the motor control (thermostat). It is general practice that the black wire is the live wire and goes from the plug, up to the motor control. The white wire returns from the motor control down through the junction box into the relay and then into the motor. The third wire is red or green and carries the current from the light switch and light back to the white wire of the extension cord. Figure 6-24.



6-25. A domestic refrigerator wiring diagram showing the wiring for the cabinet light, the electric defroster, the motor, the thermostat and the relay. (Crosley Div., Avco Mfg. Corp.)

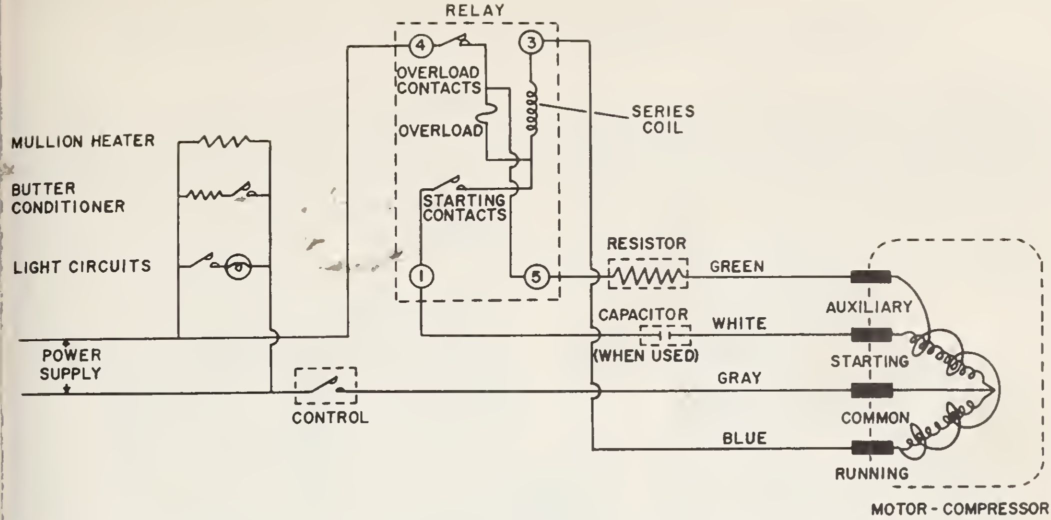
A wiring diagram of a domestic refrigerator equipped with light and a semi-automatic electric defrost system is shown in Figure 6-25. A schematic wiring diagram for a two door construction refrigerator which has a thermostat operated butter warming coil, a mullion heater to stop sweating around the freezer door, a light circuit, and a four terminal 3600 r.p.m. motor is shown in Figure 6-26. It is important that these electrical units be tested by using a test light only. Never test them by shunting them out as shunting out the resistor or relay for only one or two seconds may permanently damage the motor.

6-17. RELAYS

It is impractical to use open contacts inside a sealed system as they may cause considerable maintenance trouble, and in extreme cases may cause decomposition of the chemicals in the system under the influence of an arc. A satisfactory solution to this problem is in the Willaims-Ice-Matic in which a Mercoid Switch is used inside the dome. Hermetic units now use external circuit breakers or relays. These relays are usually of the following types:

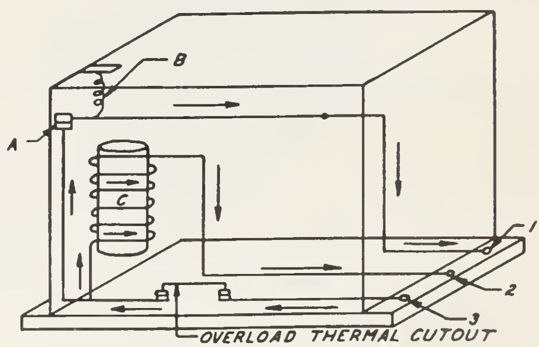
1. Magnetic amperage type
2. Hot wire type
3. Voltage magnetic type

The purpose of the relay is to permit electricity to flow in the starting winding of the motor until the motor

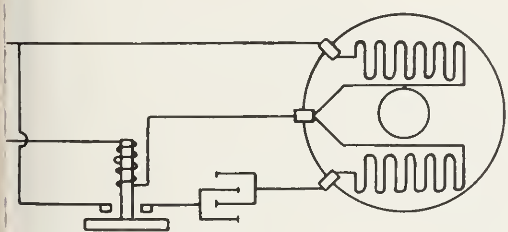


-26. A wiring diagram of a four terminal motor-compressor. This unit has three motor windings and operates at 3400 RPM. The capacitor is used in the larger units.
(General Electric Co.)

reaches about two thirds of its rated speed, and then to disconnect or open he starting winding circuit. See Chap-er 7 for motor designs. The starting winding is only energized for 3 or 4 seconds at a time. If current flows hrough this winding for a longer period of time, the winding will overheat. Many relays have protection devices to prevent the starting winding from be-ng abused.



6-28. A magnetic relay with spring loaded points (starting position). A. Contact points; B. Spring; C. Magnetic coil; 1. Starting winding terminal; 2. Running winding terminal; 3. Power-in terminal.



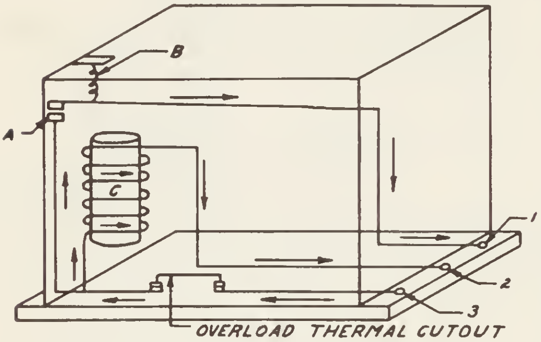
6-27. A magnetic relay system with the unit in the "off" condition.

6-18. MAGNETIC AMPERAGE RELAY

The original type, the magnetic type, uses the electrical characteristics of he motor to operate it. It is well known hat the running winding consumes more current when the stator is not turning or is turning slowly. As the rotor picks up speed, the magnetic fields build up and collapse in the motor, producing a bucking or counter electromotive force or voltage on the running winding. This counter EMF (Electro Motive Force) reduces the current draw of the running winding.

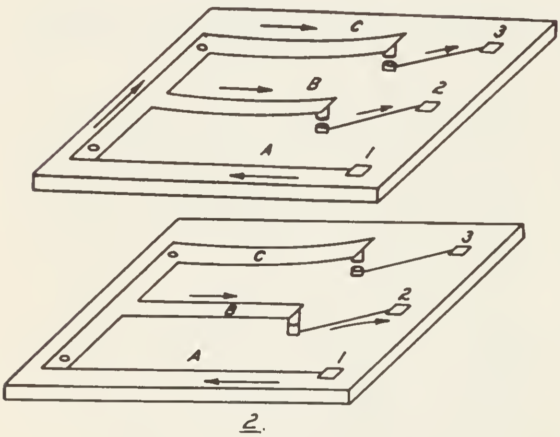
The magnetic relay is an electromagnet similar to a solenoid valve. Either a weight or a spring holds the starting winding contact points open when the system is idle, Figure 6-27. Then when the motor control contacts close and current flows into the running winding, the magnetic switch is heavily magnetized and lifts the weight and closes the contacts or overcomes

the spring pressure to do so. This action closes the starting winding circuit and the motor will quickly accelerate to two thirds or three fourths of its rated speed. As it does so, the amperage draw of the motor decreases,



6-29. A magnetic relay in the open or running position. A. Contact points; B. Spring; C. Magnetic coil; 1. Starting winding terminal; 2. Running winding terminal; 3. Power-in terminal.

the magnetic strength decreases, allowing the weight or the spring to open the contact points. See Figures 6-28 and 6-29. Most of these relays have the overload cut-out incorporated in them.



6-30. One type of resistance heated or hot wire relay. A. Hot wire; B. Running winding bimetal; C. Starting winding bimetal; 1. Power wire connection; 2. Running winding connection; 3. Starting winding connection; I. Both connections open—unit has been drawing too much current; II. Starting connection open, unit operating on running winding only.

6-19. HOT WIRE RELAY

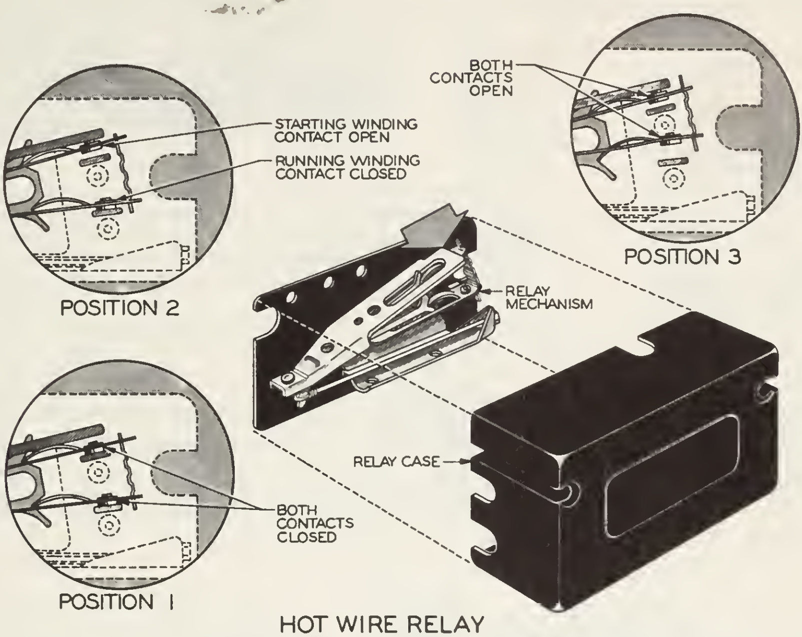
The hot wire relay is becoming more and more popular. It is a device that works exceptionally well. The theory of this control is that the electrical energy can be turned into heat energy, and that it takes time to raise the temperature of a substance, and also as a substance increases in temperature, it expands.

The hot-wire relay uses a specially calibrated wire (A) Figure 6-22, of high oxidation resistance.

Two bi-metal strips are mounted near this resistance wire. One bi-metal strip controls two contact points in the starting winding circuit (C), the other is in the running circuit (B). When the relay is closed, both sets of points are closed, and as the thermostat points close, electricity flows through the hot wire along both bi-metal strips and into both the starting and running windings (L). As all this current passes through the wire (A), it heats up, and it is exactly sized so that it heats just enough to make the starting winding bi-metal strip (C) bend as the motor reaches its proper speed (two thirds to three fourths of full speed) and the starting winding contacts open (2). The current going through the hot wire now decreases, and the running winding bi-metal (B) does not move enough to open. However, if the compressor is overloaded, or if for any other reason the running winding draws too much current, the resistance wire will heat up enough to make the running winding bi-metal strip open, and the unit is shut off. Because it takes time for the hot wire to cool and heat, and also for the bi-metal strips to cool and heat, it is necessary to wait for the temperatures to change before trying to make the hot-wire relay function again during any testing.

Another type of hot-wire relay operates on the same general principle, with

an adaptation of wire under tension to operate the contact points. Figure 6-31. This wire by its tension when cold, keeps both sets of contact points closed (1). As the current passes through the wire, it heats and expands or stretches at a very carefully predetermined setting, the stretch of the wire opens the starting winding contact points, (2) and if the motor should use an excessive amount of current, the wire will stretch or expand enough more to open the running winding contact points (safety cutout)(3). Some units that use the Delco hot-wire relay are Crosley, Gibson, Kelvinator, Norge, Philco, Stewart-Warner, Tecumseh and Universal Cooler. Figures 6-32 and 6-33 show complete wiring diagrams of refrigerators using hot wire relays.

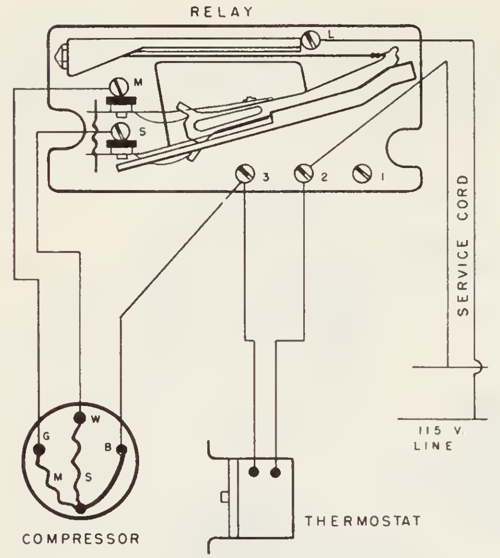


6-31. A hot-wire relay and its three operating positions. 1. Starting; 2. Running; 3. Overload. (Gibson Refrigerator Co.)

6-20. MAGNETIC VOLTAGE RELAY

The voltage relay is growing in popularity especially in the larger units. It is also called a potential type relay. Figure 6-34. This relay looks somewhat similar to the amperage relay, but its operation is based on the increase in voltage as the unit approaches and reaches its rated speed. This relay remains closed on the off cycle, and this feature is its biggest advantage. If the points are closed when the thermostat turns on the power, there should be no arcing of the relay points as quite frequently occurs with the amperage relay. As the motor speed increases, the higher voltage creates more magnetism in the relay coil pulling the contact points apart thereby opening the starting circuit. The relay coil is connected across the starting winding and is made of small wire so very little current passes through it, thus minimizing the heating of the coil and core.

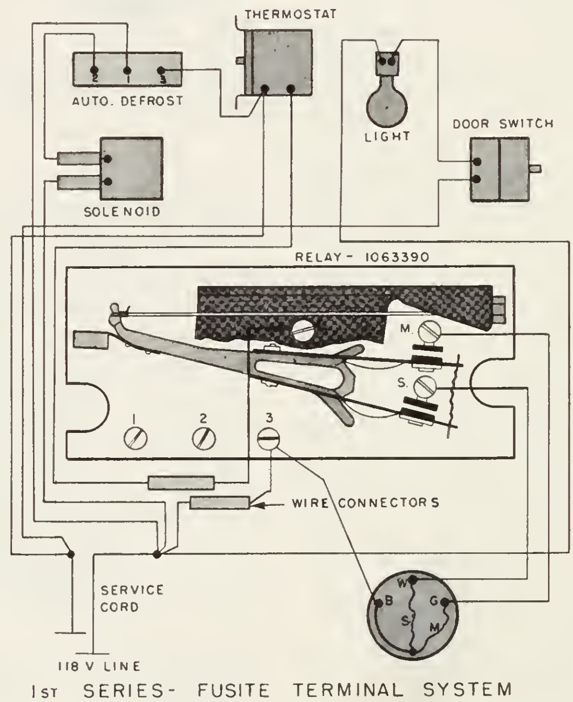
Three popular relays on the market



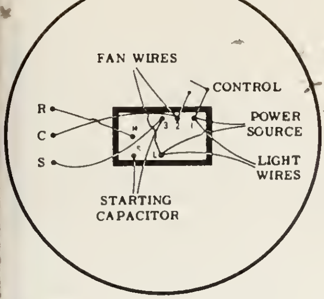
6-32. The hot wire relay. The hot wire is located just under terminal L and is horizontal. A very slight lengthening of the wire due to heating by electricity causes the starting points at S to open. Then if the wire lengthens any more the points at M will snap open stopping the unit.
(Kelvinator Div., American Motors Corp.)

6-34. Magnetic voltage relay. The points (C) are closed on the "off" cycle due to the permanent magnet or weight (A) on the right of the rocker arm. When the unit starts the points will be forced open then the voltage increases enough in the coil (B) to pull the points apart.
(Copeland Refrigeration Corp.)

are the Delco hot wire relay, The General Electric amperage relay, and the Klixon amperage relay. Figure 6-35 shows the wiring connections to these three relays.

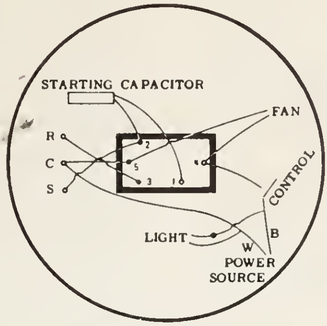


6-33. A complete wiring diagram of a refrigerator using a "hot wire" relay.
(Kelvinator Div., American Motors Corp.)



DELCO HOT WIRE

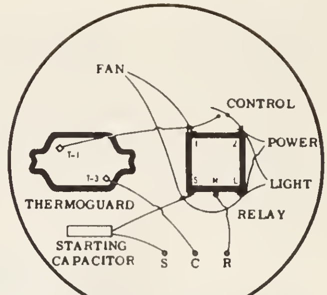
L adn 1	Power Wires
L and 1	Light Wires
1 and 2	Control Wires
L and 2	Fan if used
M and 3	Running Capacitor if used
S and 3	Starting Capacitor if used
R and M	Running Wire
C and 2	Common Wire
S and 3	Starting Wire if motor is capacitor start
S and S	Starting Wire if motor is split phase



MAGNETIC G-E

C Post and Control Power Wire
Light Directly across Power Wires
Control in Series with Post 4 and Hot Wire

4 and 5	Fan
2 and 3	Running Capacitor if used
1 and 2	Starting Capacitor if used
R and 3	Running Wire
C and 5	Common Wire
S and 2	Starting Wire if motor is capacitor start
S and 1	Starting Wire if motor is split phase



KLIXON MAGNETIC

L and 2	Power Wire
L and 2	Light Wire
1 and 2	Control
L and 1	Fan

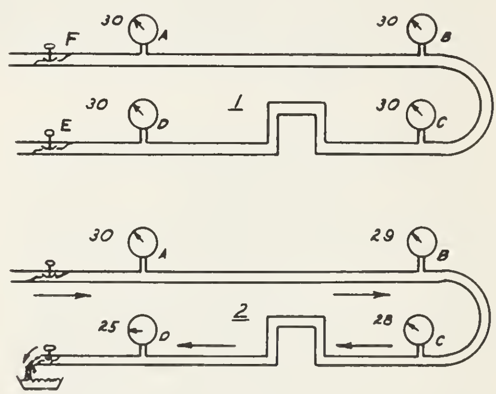
T-1 and 1 Then T-3 to common motor terminal
S and Starting Terminal for starting capacitor
If motor is split phase, starting motor terminal is attached direct to S on relay
M to Running Motor Terminal
If control is not used, use jumper between 1 and 2.
Note: Posts 1 and 2 are not on all Klixons, but all are interchangeable

6-35. The electrical wiring connections to three popular relays. (Airo Supply Co.)

-21. HERMETIC EXTERNAL ELECTRICAL TROUBLES

It is necessary to understand a little bout electricity before one can easily heck a hermetic system. Electrical roubles are actually quite simple and an be easily checked. Read Chapter 7. t is important to remember that voltge is pressure, and that amperage is uantity of electricity. One must have oth to have electrical power (watts). ust like water in pipes, the wires must e large enough to carry the current amount). The joints must be good just ke in water pipes in order for the full ow of current to take place.

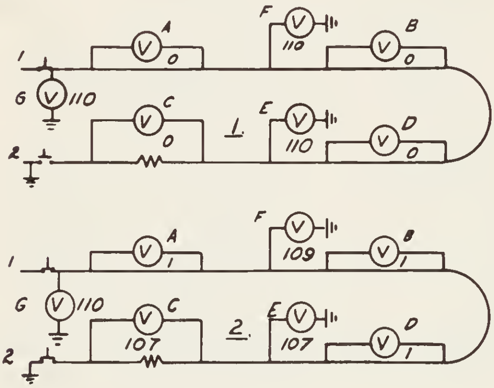
What is not generally understood is at there is always a loss of pressure olts) in a wire as electricity flows long it. This action is due to a heating ction in the wire caused by the elecron movement as the electrons collide ith each other. Figure 6-36 (I) shows water pipe with the inlet valve open



6-36. Water flow and how it is similar to electricity flow. I. Water not flowing with valve E closed, and valve F open. All gauges show the same pressure; II. With water flowing, the gauges show a pressure drop. Most of the drop is between C and D due to the U bend in the pipe.

and the outlet valve closed. The pressure is produced by the water pumps. The pressure is the same throughout the system. When the outlet valve is opened and water flows, the pressure drops. Notice that it drops a little for

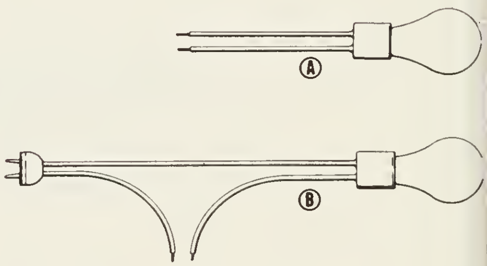
each distance. This pressure drop indicates the energy lost pushing the water that distance. Between gauges C and D the pressure drop is greatest, because additional effort is needed to push the water around the four bends in the pipe.



6-37. Electricity flow showing how potential (pressure), resistance, and potential (pressure) drop operate in a system. I. Electricity not flowing with switch 1 closed and 2 open. Pressure to ground is 110 volts, but other pressure drops are 0; II. Electricity is flowing with switches 1 and 2 closed. Pressure drop at A, B, and D is 1 volt each and the resistance at C has a 107 volt drop.

In Figure 6-37 a similar setup is drawn, but this time for an electrical system. It is important to remember that electricity is furnished by electrical companies either at a 110-volt pressure or at a 220-volt pressure. This electricity comes into the building as one white wire and one black wire for 110 volts. It is wired so the white wire is also connected to the ground. The black wire is the hot wire, and a voltmeter between it and ground will show 110 volts. The 220-volt circuit usually consists of three wires; two black and one white. The voltage pressure (voltage) between the two black wires is 220 volts while the pressure between either of the black wires and the white wire is 110 volts. Frequently, however, the white wire and black wire in a building become confused, and one must use a voltmeter or test light to indicate which wire is hot and which is the ground wire.

As most electric refrigerators are plugged into wall receptacles, it may not be known which lead or wire is hot. Reversing the plug will sometimes minimize radio noise and, in some extreme cases, even cause the unit to operate better. In Figure 6-37 a black wire extends from the switch at point G to the right side of the resistance, light bulb or motor at point C. The switch at point (1) is closed, but the one at point (2) is open. The potential or voltage is 110 volts up to the number 2 switch. However, no electricity is flowing (open circuit) and, therefore, there is no voltage drop along the line. Voltmeters A, B, C and D show no voltage (there is no pressure difference between their connections to the main line). The voltmeters at E, F, and G show the full 110 volts, because that is the pressure difference anywhere along the line and the ground. In Part II the switch at (2) is closed and current starts to flow through the circuit (closed circuit). Note that now there is a small voltage drop at A. This voltage



6-38. The two types of test lights. A. This is a light bulb 25 watt heavy duty connected to the two prongs; B. The test light is connected to an electric power source and is used to check circuits not connected to a power source. (Franklin Mfg. Co.)

drop occurs in any line in which current is flowing. If the line is large enough, the voltage drop is very small (.001 to .0001 of a volt). If the line i

small for the current flow, the voltage drop will be greater. Usually an under-sized wire may be detected by the fact that it gets warmer than usual while current is flowing. The voltage difference between the line and the ground is less at F and E because of the voltage drop in the line up to these measuring points. At C the voltage drop is 107 volts, the remaining pressure difference between the hot wire and the ground. Note that if there was more voltage drop at A, B and D, the voltage at C would be less. This is one serious source of motor trouble. If a motor is designed to operate at 90 to 110 volts and the voltage drop in the circuit is large, the motor voltage may be so low at the motor that the motor will lose speed and start slipping its magnetic fields. This causes the magnetic fields to grow large at the wrong time, and the motor will heat up fast, and it may even burn up.

It is vitally necessary that the external electrical circuits of the refrigerator are in good order and of the proper capacity. All the connections must be good, electrically speaking.

In actual practice a voltmeter using several scales and with needle point leads should be used to check voltages and voltage drops. This voltmeter should have a 150 volt scale.

6-22. TEST LIGHTS

One of the best methods to test electrical circuits without causing any damage is to use a test light. Figure 6-38. Test light "A" is used where the device being tested is connected to electrical power. For example, if the refrigerator is plugged in and won't start, this test light is used to determine if power is coming to the wall outlet. The lighting of the light indicates power is available up to the wire probes. If the wall outlet has power then the open circuit is in the refrigerator. Plug the refrigerator into the wall outlet. Use the test light to see if power is coming to the end of the extension cord that fastens to the junction box or relay terminals. Continue this testing until the open spot in the circuit is found.

Test light "B" is used to check electrical devices that are not connected to power. This test light is then connected to a power source. If the bulb lights when the probes are touched together, the test light is functioning. To use this light put one probe on one end of a wire and the other probe on whatever that wire is supposed to connect to. If the bulb lights the circuit is continuous.

6-23. SERVICING RELAYS

The servicing of relays is mainly to determine if they are defective, and then to replace them with an exact replacement. These relays are very accurately designed to fit the unit. The wire size, the contact point area, and the spring tension or weight plus the air gaps must be very accurately set. A very slight difference in weight or spring tension, for example, may necessitate a hundred revolutions difference in the functioning time of the points if they function at all. The most effective way to determine if the relay is causing the trouble is to check all the other parts of the circuit, i.e., the motor, the capacitor, the overload cut-out, and the thermostat.

It is very necessary to keep the relay cover in place; never discard it, as dust collecting on the contact points will quickly burn the points resulting in too much voltage drop across the points and poor functioning of the control. The weight-type amperage relay must be mounted in a straight up and down position so the plunger will not rub and bind against the sides of the relay body,

Figure 6-39. The relay should open in approximately three seconds if it is functioning correctly, Figure 6-40.

When replacing the relay, it is important to disconnect the power supply, to label each wire as it is disconnected, and to use the correct size screwdriver. The terminals are usually numbered, and a tag or clip on each wire with the corresponding number makes it easy to rewire the new relay. Masking tape is very useful for labeling wires. Inasmuch as a dropped screw is sometimes hard to locate, it is recommended that the screw holding type of screwdriver be used.

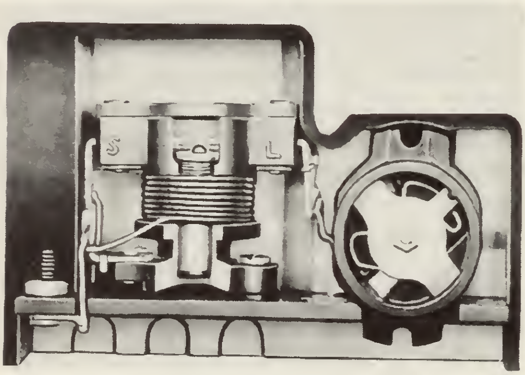
6-24. OVERLOAD PROTECTION

Refrigerating systems must be protected against too much current draw or against overheating. Chapter 7 describes these overload devices in detail.

6-25. TROUBLES

The troubles that may be encountered in thermostats are: (1) corrosion occurring at the contact points causing a poor electrical circuit, which does not allow the motor to run. This trouble may be remedied by sanding the points with sand paper, not emery cloth, and it is advisable to use as fine a grade as can be obtained. A very fine mill file may also be used to clean open contact points. (2) The overload protection devices may also have dirty contact points, and poor current flow will result. (3) the power element and bellows frequently lose their charge through some leak. This may be detected, because, if the charge is lost, the bellows are very easily compressed with one's fingers. If the bellows were charged, the pressure inside would probably be around 75 pounds per square inch or more, and finger pressure would not affect it. In the event of leakage, replace this part of the switch. (4) Frequently the bellows is not screwed up tightly into the socket, causing a total change of temperature range before the motor will cut-in and cut-out. The servicing of these particular types of

6-40. An amperage-magnetic relay. This control keeps the starting winding points open by means of a cantilever spring. Only when current first flows through the magnetic coil is the magnetism powerful enough to lower the spring and close the starting circuit at "A." If the unit consumes too much current, the resistance wire coil "B" will heat and bend the bimetal strip "C" and open the circuit at "D."
(Copeland Refrigeration Corp.)



6-39. An amperage-magnetic relay. The plastic housing contains a magnetic coil with a movable center. Only when current first flows is the magnetism strong enough to raise the center piece and close the starting winding circuit. The device at the right is an overload cut-out.
(Copeland Refrigeration Corp.)

switches is rather difficult; it is therefore the best policy simply to replace the complete unit.

The power element must be firmly clamped to the cooling coil. Good thermal contact must be obtained between the thermal bulb and the coil. Many cooling coils have metal sockets into which the thermal elements are inserted.

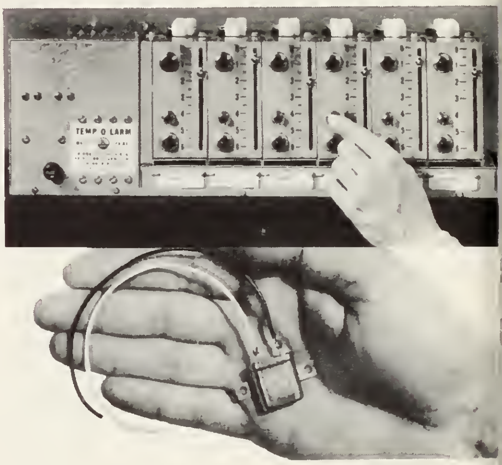
6-26. REVIEW QUESTIONS

1. What kind of motor control must be used with an automatic expansion valve? Why?
2. In what way are the pressure and the thermostatic types of motor controls essentially similar?
3. What two purposes does a motor control serve?
4. How many types of differential adjustments are there?
5. What are thermostatic motor control bulbs charged with?
6. Why are starting relays used in connection with hermetic motor controls?
7. What does the range adjustment control?
8. What does the differential adjustment control?
9. What provisions are built into the motor controls to protect the motor from drawing too much current?
10. Will turning the cut-in differential affect the cut-out temperature?
11. Will turning the double type differential affect the cut-out temperature?
12. Are clocks used to provide automatic defrosting?
13. What is another name for a relay?
14. How many types of relays are in use?
15. What type screwdriver is recommended for small terminal screw handling?
16. How may a thermostat be quickly checked?
17. Why is a relay necessary for hermetic motors?
18. What is the voltage drop?
19. Why does a loose connection become warm?
20. Which magnetic relay coil uses the largest size wire?
21. Does a hot wire relay have to be mounted level? Why?
22. How should open contact points be cleaned?
23. Why do the electrical wires have different colored insulations?
24. Is the current draw more when the motor is starting or when it is running?
25. Is the voltage drop more when the motor is starting or when it is running?

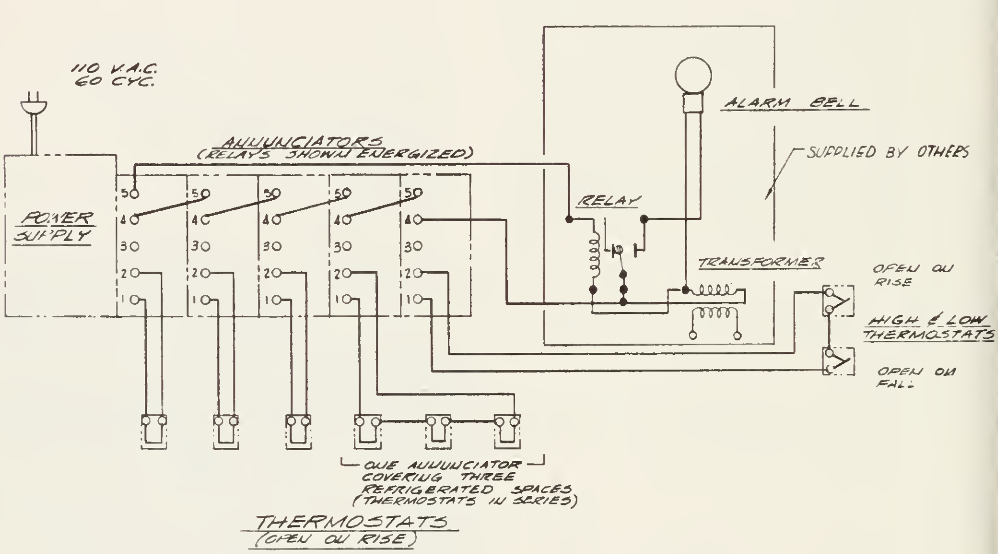
6-27. ELECTRONIC WATCHMAN

There is an ever present hazard in connection with all refrigerated cabinets or containers. This hazard is possible failure of some part of the refrigerating mechanism and the consequent loss of perishable commodities.

Quite a number of refrigeration installations now include some kind of device which warns the owner or operator when some of his refrigerated stores are warming to a dangerous temperature. Many of these devices depend on dry cells for their operation. Such installations may deteriorate. If the dry cells are not replaced periodically they may fail to give a warning signal when needed. A transistor warning device has been developed which requires very little current for its operation and can be depended on to give warning if needed. Fig. 6-41 shows a transistor-type warning device designed for use with six separate fixtures.



6-41. A transistor warning device which will indicate trouble conditions by energizing warning lights on a temperature rise.
(Kidde Ultrasonic & Detection Alarms, Inc.)



Chapter 7

ELECTRIC MOTORS

The compression type refrigerating system must have a power source or energy source to turn the compressor. Many means have been used, such as man power (Boer War in Africa), steam engines, diesel engines, gasoline engines, electric motors, etc. The electric motor is the most popular for the small and medium size units because of its simplicity, quietness, and ease of automatic control. The electric motor changes electric energy into mechanical energy.

7-1. ELECTRIC MOTOR APPLICATIONS

Electric motors used to operate refrigerating systems may be classified as open motors or sealed-in (hermetic) motors. The open motor drives the compressor directly or by means of a belt. The sealed-in, or hermetic motor, is installed inside the compressor dome and usually drives the compressor directly.

7-2. TYPES OF ELECTRIC MOTORS

Many types of electric motors have been used with refrigerating mechanisms. The most popular types used are:

1. The split-phase motor
2. The repulsion-start induction motor
3. The capacitor-start motor
4. The capacitor-start, capacitor-run motor
5. The shaded pole motor
6. The direct current motor

The repulsion-start induction motors have been used since 1918. These were the only motors recommended for the conventional belt-driven compressor until a few years ago. One exception was an early Copeland unit, which used an induction motor on a belt-driven unit and had a centrifugal clutch pulley which allowed the motor to start without a load.

Direct current motors are used in localities which are supplied with direct current only.

The capacitator motor is now being used extensively in place of the repulsion-start induction motor and it is used almost exclusively in the hermetic machines with a starting winding to take up starting loads.

7-3. BASIC ELECTRICITY

Before one can understand motors, one must know some basic electricity. Electricity is a form of energy.

All matter is made of molecules; all molecules are made of atoms. Finally, all atoms are made of electrons and protons. Electrons are negative charges of electricity. Protons are positive charges of electricity. If an atom collects an extra electron for a moment, it is negatively charged. If an atom loses an electron momentarily, it is positively charged. The electrons

travel from surplus electron atoms to an atom with a lack of electrons.

Electricity is the flow of these electrons or negative charges. The number of electrons that flow are called coulombs (it is calculated that 6,900,000,000,000 electrons equal one coulomb). One coulomb flowing for one second equals one ampere. The ampere is known as the quantity of electricity.

If there is a large excess of protons, and electrons move to make up the difference; the eagerness with which they move or their desire to move, it is called voltage or pressure difference.

Electric current consists of electrons traveling in a conductor either solid, liquid, or gas. Electrons are the revolving particles of an atom. They revolve around a center made of protons. Electrons are attracted by protons. Therefore, electrons will flow toward a substance that is temporarily short of electrons (has an excess of protons).

Electricity can be created from the other energies such as heat energy, mechanical energy, etc. Any method which produces an unbalance in the electrons or protons causes an electrical potential.

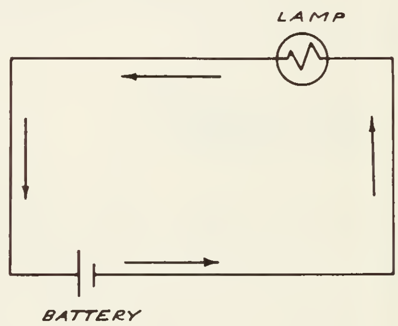
Electricity is related to magnetism. If a wire cuts a magnetic field, electricity is produced in the wire, and conversely, if electricity is passed along a wire, a magnetic field is created around the wire. By correctly using the magnetism created by electricity, we can make an electric motor (turn electrical energy into mechanical energy) or an electro-magnet (solenoid valves, relays, etc.).

Electrical engineers and scientists have established standard voltage systems for use in homes and industry. Most systems operate at a 115 volt pressure difference and in some areas at a 230 volt difference. This pressure difference permits substantially built electrical apparatus to operate fairly efficiently.

There are two kinds of electricity used today. Direct current (D.C.) means that electricity flows in one direction at all times; alternating current (A.C.) means electricity that for one instant flows in one direction in a wire, and in the next instant flows in the other direction. Normally A.C. cycles each one sixtieth of a second (60 cycle). This cycle means that for 1/120 of a second the current will flow in one direction and for 1/120 of a second it will flow in the other.

7-4. VOLTS

The desire of electricity to flow is called electro-motive-force and is initialed EMF.(E) The unit for EMF is volt. A dry cell has an EMF of $1\frac{1}{2}$ volts, a wet cell has an EMF of 2.1 volts, and most household electricity has an EMF of 115 volts.



7-1. A simple electrical circuit with a one cell battery, two wires or conductors and one lamp.

7-5. AMPERES

The number of electrons flowing in the conductor is called coulombs. If one coulomb flows or drifts along a conductor each second, this rate of flow is called amperes and is the intensity (I) of the electricity. Ampere flow is also known as current.

7-6. RESISTANCE

The difficulty that the electrons encounter drifting in a conductor is called the resistance.(R) Energy is wasted by this resistance and is revealed by the heating of the conductor as the electricity flows in it. The unit for resistance is the ohm. If it requires an EMF of one volt to cause a current intensity of one ampere to flow, the resistance of the conductor is one ohm.

7-7. OHM'S LAW

The relationship between the volt, the ampere, and the ohm is known as Ohm's Law. It has been found that if a wire one foot long will allow one ampere to flow with an EMF of one volt, this same wire will allow two amperes to flow if the EMF is two volts. Therefore, it seems that the EMF is the product of the intensity (amperes) times the resistance (Ohms) or:

EMF = intensity X resistance.

$$E = IR$$

and therefore $I = \frac{E}{R}$

and therefore $R = \frac{E}{I}$

One may learn from this basic law that if the resistance stays constant, the current can only be increased by increasing the voltage. Also, if the resistance becomes very small in a circuit, the amperage will become very high. For example, a 1/3 H.P. motor draws 4 amperes.

$E = IR$

$115 = 4 \times 30$

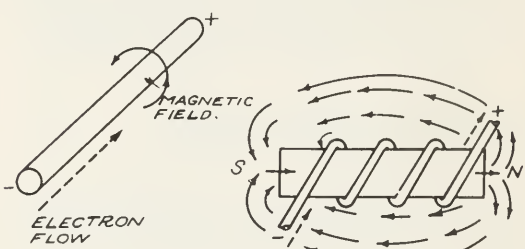
If a short occurs so the resistance is reduced to 5 ohms, the current must increase to 23 amperes, and if the fuse doesn't "blow," the motor windings will become too hot as they try to carry this excessive current, and the insulation will burn up.

7-8. CIRCUIT

An electrical circuit is a complete path or paths for the electrons to follow. It might consist of a battery, two wires, and a lamp. When the wires are connected from the two lamp terminals to the two battery terminals, the lamp will light, indicating that current is flowing out of the battery along the wire, through the resistance in the lamp, and back to the battery along the other wire, Figure 7-1.

To have electrical flow one must have a circuit. A circuit is an electrical flow that leaves an electrical source (battery, generator, or induction coil) and returns to the same source. Continuity is the term applied to a continuous path for the electrical flow.

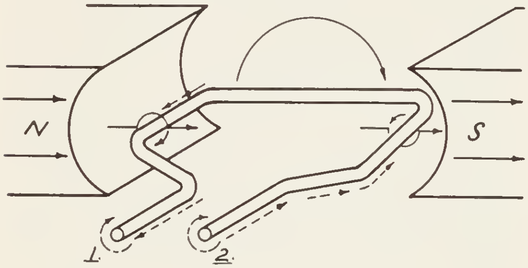
When the circuit is complete, it is called a closed circuit, and there is a complete path for the electrons to follow; or it may mean a continuous



7-2. Showing the relationship between electron flow and magnetism.

circuit. The closed circuit is known as having continuity. An open circuit is an interrupted circuit meaning one with an open switch or a broken wire. A short circuit is that condition where the electrons have a short cut to follow to get back to their source. As an example, a small wire could be put across the terminals of the lamp. Because most of the electrons flow along the path of least resistance, the wire will now carry most of them, and the light will

go out. The amperage flow will greatly increase (because of a decrease in resistance), and usually trouble occurs. Another more common example is the touching of two adjacent wires. A ground is where a wire touches some of the metal structure of the device. An example is a bare field winding wire touching the frame of the motor.



7-3. Generation of current. The wire loop (1 and 2) is turning clockwise. As the wire near the N pole cuts the lines of flux, the flux is bent clockwise around the wire. As the wire near the S pole cuts the flux lines the lines bend around the wire contra-clockwise. The left hand rule then determines direction of electron travel (broken arrow lines). When the loop turns 1/2 revolution or 180°, the wire (1) will now bend the flux lines and produce current flowing in the opposite direction.

7-9. ELECTRO-MAGNETS

All magnets have two poles or areas of magnetic intensity. These poles have unlike magnetic characteristics. They are called North and South poles due to the fact that the magnetic poles of a compass are attracted to the North and South magnetic poles of the earth. Like poles repel each other (two South poles or two North poles). Unlike poles attract each other (a South pole is attracted or pulls toward a North pole).

If a wire is coiled around a steel core (of a good magnetic material), and current is passed along the wire, the core becomes magnetized.

Figure 7-2. The power of the magnet is controlled by the number of turns of wire around the core and by the number of amperes flowing along the wire. A soft iron core increases the power of the magnet as it aids the magnetic lines of flux to concentrate in the core. The core is made of layers of soft iron, because these layers keep internal magnetic circuits to a minimum, and these localized eddy currents prevent overheating of the magnet.

7-10. DIRECT CURRENT

There are electrical circuits in which the current flows in one direction all the time. This direct current is the type of current that is produced by dry cells, storage batteries, etc. Some power companies still produce and sell direct current (D.C.), but its use is fast disappearing in the electrical power industry.

7-11. ALTERNATING CURRENT

When the current first flows in on direction along a conductor and the reverses itself and flows in the opposit direction along the same wire, th current is said to alternate its directio of flow. Alternating current (A.C.) i the type of current that all generator produce, because the wires of th generator first cut the magnetic field i one direction and then in the othe direction, thus producing an alternat or opposite flow for each revolution o for each magnet passed, Figure 7-3.

7-12. CYCLES

If the electricity flows for 1/ second in one direction and then fo 1/2 second in the other direction in wire, it is called one cycle. Mos electricity is created at 60 cycles which means that in one second th electricity flows 60 times one way an 60 times the other, or 1/120 of a secon one way and then 1/120 second th other way.

This reversal of the current flow can be shown by a graph, Figure 7-4.

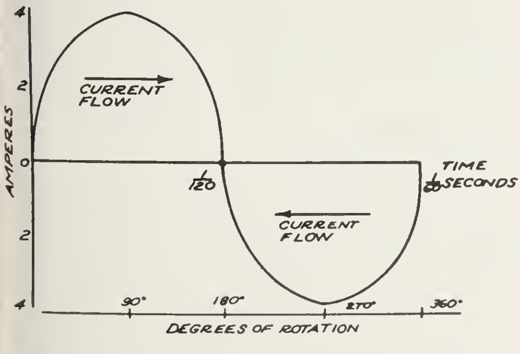
This drawing shows a sine wave of 60 cycle alternating current.

Note that the current flow is zero at the start and that the current builds to a peak (the wire is now perpendicular to the magnetic lines of force). Then the current tapers off to zero at the end of 1/120 of a second. As the wire crosses the magnetic lines in the opposite direction, the current increases again, but in the opposite direction. At the end of 1/60 of a second the current flow is again 0. The cycle will now repeat itself.

7-13. INDUCED MAGNETISM

A property of magnetism is that it produces magnetism in some other metals near it, Figure 7-5.

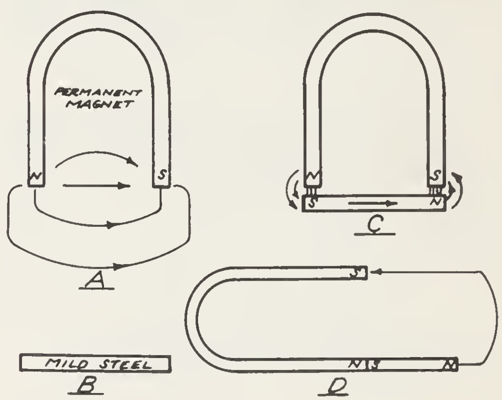
In this figure, the permanent magnet is surrounded by its magnetic field, but the mild steel piece has no magnetism. If the mild steel piece is put near the permanent magnet or is touching it, it too becomes a magnet. Thus any material that is able to be magnetized will become a magnet if immersed in a magnetic field. It must be remembered that a magnetic field's power decreases as the square of its distance from the source; that is, a magnetic field is four times stronger, 3 in. from a magnet, than it is 6 in. from it. $(6/3)^2 = 2^2 = 4$. Or if it is nine times as strong at 3 in. away as at 9 in. $(9/3)^2 = 3^2 = 9$.



7-4. A graphic picture of the flow of 60 cycle current. The peaks of the curve are those times when the conductor is moving at right angles to the magnetic lines of force.

This magnetic inducing or induction is used in electric motors by making the rotor of mild steel, etc., where magnetism is induced by the magnetism of the stator magnets or field windings.

Induced magnetism is useful in electric motors, because, by putting electrical windings on the field poles, magnetism can be created or induced in the rotor. There is a very slight time delay in this induction, and, therefore, if the rotor is once started turning, the rotor will continue to turn, because the field pole (stator) is always opposite in polarity. By the time the field pole changes its polarity, it induces an opposite pole in the stator, which repels the rotor pole toward the next stator pole, which has become an



7-5. The magnetic fields surrounding magnets. A. Lines of force from N to S; B. A mild steel nonmagnetized steel bar; C. Magnetism induced in the mild steel bar; D. Another sample of induced magnetism.

opposite pole. The rotor will turn almost the full distance between the two poles before the induced magnetism can be changed. It is also important that the magnetism takes time to build up to its magnetic strength because of the 1/120 of a second it takes the magnetism to change from full strength N to a full strength S pole.

7-14. THE ELEMENTARY ELECTRIC MOTOR

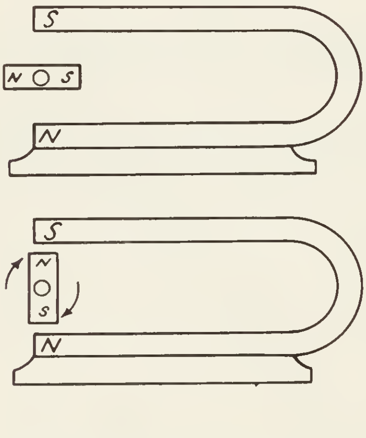
Electrical energy can be changed to mechanical energy in a device called an electric motor. This change is produced by changing the electrical energy into magnetism. Because like poles repel (N repels N and S repels S), and because unlike poles attract (N attracts S and S attracts N), one can produce motion by putting one magnet on a shaft and mounting another in a fixed position.

Figure 7-6. The bar magnet on the shaft will turn until its S pole is close to the fixed N pole, and the shaft bar magnets N pole is near the fixed S pole. Because the fixed magnets are stationary, they are called stator; because the other magnets rotate, they are called the rotor.

The rotor will now stay in the vertical position unless something is changed. If the magnetism of the stator, or of the rotor is now changed, the shaft will rotate another 1/4 turn.

The magnetism is changed by using electro magnets instead of permanent ones, Figure 7-7. Now, when the rotor reaches the vertical position, the alternating current reverses, due to its cycling, and the stator polarity reverses. The stator N pole is now near the rotor pole, and they will repel each other. The S pole of the rotor is now near the S pole of the stator, and they will repel each other. The rotor will now turn or revolve one half a revolution or 180 degrees. If the rotor turns 1/2 a revolution during 1/2 of 60 cycles, then it turns 1/2 turn during 1/120 of a second. It will then turn 60 revolutions per second or 60 x 60 seconds, 3600 revolutions in one minute.

If four poles are used in the stator, the motor will only turn 1800 revolutions per minute, because the rotor will only turn 1/4 of a revolution in 1/120 of a second, Figure 7-8.



7-6. How a magnet mounted on an axis will turn when put in another magnetic field.

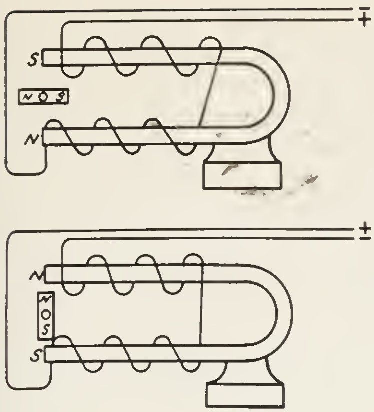
7-15. THE MOTOR STRUCTURE

Before each type of motor is studied, it is necessary to know the physical make-up of the motors.

The two main parts of a motor are the stator and rotor. The stator is also known as the frame. This frame is usually cylindrical in shape. The field poles which have the field windings on them are usually fastened to this stator and are a part of it. The identification plate is also mounted on the stator. The mounting device is mounted on the stator.

The rotor is the revolving or rotating part of the motor. It is sometimes called an armature. This rotor is mounted on a shaft and the shaft is equipped with two journals for the motor bearings.

The ends of the motor usually hold the bearings which the rotor shaft turns in. These end bells or end plates are fastened to the stator or frame. The end bells are carefully lined up to the stator because the bearings must be accurate to provide .001 in. to .002 in. clearance between the field poles and the rotor. The motor bearings are



7-7. How electricity can be used to produce the stator magnetism and turn the magnet mounted on an axis.

designed to provide for the end play of the rotor. These bearings are commonly made of brass or bronze. Very often the refrigerator dome is the stator, and the compressor bearings also serve as the motor bearings in hermetic units.

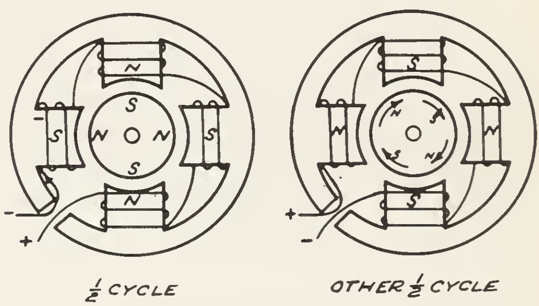
7-16. INDUCTION MOTORS

Induction motors have no windings on the armature. The turning or torque is produced by induced magnetism. Practically all motors are a form of an induction motor. One or more field windings are placed on the stator and as the alternating current passes through these windings it induces a magnetic field; this magnetism in turn passes through the armature inducing an electrical current and an opposite magnetic field in it so it revolves as it attempts to keep up with the changing field polarities.

To start these motors in the same direction each time, an exciter, or off-center field pole is put in the stator, and a centrifugally operated switch allows the current to go through this coil only when the motor is stopped or running slowly. Induction motors placed inside the hermetic machines use two field windings: (1) a starting winding, (2) a running winding. An external relay is used to disconnect the starting winding as soon as the motor reaches approximately 75 per cent of its full speed.

7-17. CONVENTIONAL SYSTEM MOTORS

There are two main types of motors used to drive the open model compressors. These motors are usually connected to the compressor by means of V- belts. The speed reduction is usually about three to one. This reduction means that the compressor flywheel is three times larger than the motor pulley diameter.

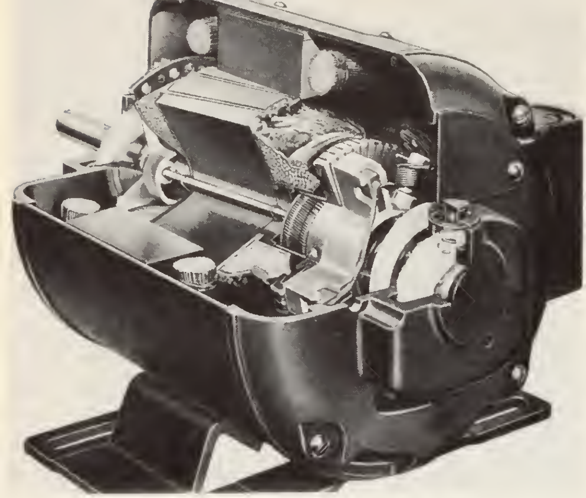


7-8. A four pole stator and how it produces one quarter turn of the armature as the current reverses in the field windings.

The two types of motors are:
1. The repulsion start-induction run motor Figure 7-9.
2. The capacitor start-induction run motor.

7-18. MECHANICAL DESIGN OF OPEN MOTORS

The conventional motors are all very similar in design. The stator is a piece of mild steel rolled into a cylinder and welded. The ends are carefully machined in relation to the machined inside surface of the stator. Field poles also made of mild steel are attached to the stator by means of large counter sunk machine screws.



7-9. A repulsion start-induction run motor. A $\frac{1}{2}$ H.P. motor with a rigid motor mount one quarter cross section. (Wagner Electric Corp.)

Iron end bells or end frames are carefully fitted to the stator by means of machine screws. Some of these machine screws extend the length of the stator and attach the two end bells together. The machined face of the stator and the end bells insure perfect alignment. These end bells hold the rotor bearings (they are actually bushings) or hold the ball bearings in which the shaft revolves. The bronze bushings are lubricated with No. 30 SAE or 300 viscosity oil.

One of the end bells also holds the brush mechanism or centrifugal switch mechanism. The other end bell has a through bushing, and the rotor shaft extends through this bushing and is carefully machined to the shaft diameter. This shaft extension also has a flat keyway machined in it, or it has a flat spot machined for an inch or two of its length. The pulley fits on this shaft extension, and a key or a set screw prevents the pulley from slipping on the shaft.

7-19. FOUNDATION

A solid substantial foundation should be provided for the installation of any motor. When the motor is mounted upon the foundation, it should be bolted down securely; when so fastened the armature shaft should be level for a horizontal motor and should be plumb for a vertical motor.

Refrigeration motors are commonly mounted on a steel base which also holds the compressor and the condenser. A rubber or spring suspension is often used on the motor to reduce the vibration and to take up the starting torque. Some motors are mounted on cradles, and springs are used to give automatic belt tension. An innovation is to mount the motor on a cradle in such a manner that, as the motor starts, the extra torque loosens the belt, and the belt tension returns to normal when the motor reaches its full speed.

7-20. MOTOR LUBRICATION

Open motors are lubricated in various ways based on the type of bearing used and the position of the motor. Open motors using bronze plain bushings are lubricated in two different ways: (1) Wick system, (2) Slip ring system.

The wick system uses a well or reservoir in the end bell and a wick (cotton or wool yarn) carries oil from this well to the top of the bushing and shaft. This system permits long intervals between servicing bearings, and i prevents excessive oiling of the bearing.

Motors equipped with this system o lubrication, when shipped from the factory, have the cotton or wool yar saturated with oil. However, before starting the motor, the oil wells should be filled by adding alowly to each oi well the amount of oil designated on the tag attached to the motor, or until oi appears in the lower oil level cup.

If the bearing is removed from the shaft, the yarn should be lifted from the bearing before replacing the shaft in the bearing to prevent its being force

between the shaft and the bearing. When replacing the yarn, equal amounts should be packed on each side of the bearing, and so located over the slot of the bearing that the spring on the oil well cover will press the yarn down on the shaft. Wick lubricated bearings should be oiled every six months.

Many of the older model refrigeration motors used the ring lubricating method. A brass ring rests on the motor shaft through a slot in the top of the bearing. The ring is large enough to dip into the oil pocket below. As the motor shaft turns, the ring revolves slowly and the wet portion lubricates the bearing. Be sure to check the rings when working on these motors. Use a medium grade automobile oil for a lubricant.

Some motors use ball bearings. These bearings are grease lubricated. Most of them are sealed bearings and do not require any lubrication service. Some, however, are equipped with grease cups and can be grease gun lubricated. These motors when new are supplied with enough grease in the bearings to lubricate them for a number of months. A small amount of grease should be added every two or three months. Use a high grade "Medium" grease on fully enclosed motors. Too much grease will overheat the bearings. The life of the bearing depends on cleanliness. Use only clean grease and keep all dirt out of the bearing. Clean all the connections before using the grease gun.

7-21. CLEANING THE MOTOR

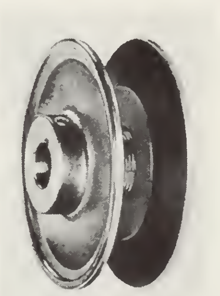
The motor in service should be cleaned periodically. Dust and lint in the motor will prevent proper air circulating through the inside of the motor. Compressed air or a hand-bellows should be used frequently to blow all the dirt out of the motor. Any oil which may overflow from the bearings should be wiped from the motor. A little attention in this regard will result in continued satisfactory operating results and enable the motor to give the best service for many years.

If the motor is dismantled, all the parts should be carefully cleaned prior to being worked on and prior to assembly. Cleaning fluids must be used that are not harmful to the electrical insulation material.

All cleaning fluids should be used in well ventilated and fireproof situations. Only sufficient cleaning fluid for the job should be used as any excess may be dangerous.

7-22. PULLEYS

The pulleys that are mounted on the motor shafts are available in a variety of sizes and construction. Some are made of cast iron and some are fabricated of steel stampings. They are made with several shaft size openings and in a large variety of diameters.



7-10. A standard Vee pulley using a set screw fastening device.
(Maurey Mfg. Co.)

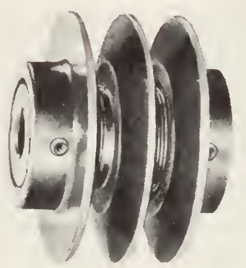
The pulleys are also made with and without fans.

The most popular shaft sizes are 1/2 in., 5/8 in. and 3/4 in. diameter. Practically all pulley bores have a keyway and a set screw. The set screw usually has a 5/16 in. NC thread.

The pulley sizes vary from 2 in. diameter to a 5 1/4 in. diameter in 1/4 in. increments. Larger sizes up to 15 in. diameter are available.

The V-pulleys come in two popular widths. The "A" width is for belts up to 17/32 in. width while the "B" width is for belts that are 1/2 in. to 11/16 in. wide.

Multiple groove pulleys are available for units that use two or more belts to drive the flywheels. Some air conditioning units use step pulleys. By changing the belt from one groove to another, the speed of the fan can be varied.



7-11. A double belt Vee pulley. Both grooves are adjustable and enable a variety of speeds. (Maurey Mfg. Co.)

Special pulleys that are of variable pitch are also available. These pulleys are made with one half of the pulley threaded on the hub of the other half, Figure 7-10. A set screw locks the variable half in place when it is adjusted. By turning the variable half, the V- groove can be widened to permit the belt to ride closer to the hub and thereby reduce the speed of the driven flywheel or pulley. The speed of the driven unit can be varied by as much as 30% using these pulleys. Figure 7-11 illustrates a double groove variable pitch pulley.

Bushings are available to adapt large bore pulleys to small shafts; for example, a bushing can be used to reduce a 3/4 in. bore to a 1/2 in. bore.

7-23. BELTS

The most popular way to drive the conventional compressor is to use the V- belt. These belts are made of rubber, layers of fabric, and cord. Some belts are a mixture of natural rubber and synthetic rubber.

The belts are made in a multitude of lengths varying from as short as 15 in. outside length to as long as 364 in. outside length. The outside length is the complete distance around the outside of the belt. A steel tape, a cloth tape, or a special belt measuring fixture can be used to quickly determine the length of the belt.

Most belts are in one of two standard widths. This width is the widest or outside width of the belt. The two widths are "A" 1/2 in. wide and "B" 5/8 in. wide. However, many special width belts have been made such as 33/64, 9/16, 37/64, 19/32, 5/8, 41/64, 23/32, 3/4, 7/8, 29/32, and 31/32.

A few applications use the "C" width belt which is 15/16 in. wide.

In most cases both the flywheel and the pulley have a V- groove to fit the belt, but some units use a V- pulley and a flat flywheel. The larger size of the flywheel permits sufficient traction without using a V- groove and by using a flat flywheel the belt automatically aligns itself if the two shafts are parallel. When the motor is belted to the driven machine, it is necessary to have both shafts parallel to make the belt ride properly on the pulleys.

Whenever possible, the direction of rotation should be such as to cause the pull to be on the bottom side of the belt.

The belts should be snug but not tight. The belt should move about 1/2 in. out of alignment when pressed with approximately 10 pound force.

The development of new rubber new cording design, and materials

permits the use of smaller cross-section belts. It is imperative when installing these belts to be very careful to adjust for proper belt tension and also for alignment. The proper belt tension is secured when the belt will have about one inch play; that is, the belt should be loose enough to move out of its original line about one inch. The

"A" SECTION—Nominal Dimensions: Top width ½", thickness 5/16", angle 42°.

(Belts 120" and longer have construction as shown for "C" Section.)

"B" SECTION—Nominal Dimensions: Top width 21/32", thickness 13/32", angle 42°.

(Belts 120" and longer have construction as shown for "C" Section.)

"C" SECTION—Nominal Dimensions: Top width ⅞", thickness 17/32", angle 42°.

(Belts under 120" in length have construction as shown for "B" section.)

7-12. The three standard belt cross-sections for fractional horsepower drives.
(Goodyear Tire & Rubber Co.)

compressor flywheel and the motor pulley must be in line with each in two different ways to give long life to the belt and to the electric motor. First, the center line of the compressor must be parallel with the center line of the electric motor shaft; second, the pulley grooves must be in line with each other. The reason a poorly aligned belt will decrease the life of the electric motor is because the motor is not designed to stand an end load, and a noisy, poorly operating motor will result.

7-24. MOTOR CONNECTIONS

Except for reversible and some special motors, motors are usually provided with two or four leads for connecting the motor to one of two different voltages.

Either 110 or 220 volts (or such other corresponding voltages) are equally satisfactory, providing the voltage is maintained at the motor terminals; they may be used on circuits having voltage 100 to 120 or 200 to 240 volts.

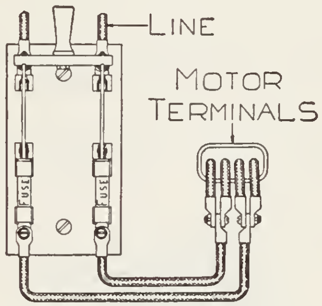
Since it is common practice in the installation of small motors to install wires with a view to mechanical strength, it is recommended that, as far as possible, all motors be installed to the 220-volt service. If the wires are of liberal size, this will result in more certainty of good voltage at the motor terminals and especially when the motor may be overloaded, Figure 7-12.

Most repulsion start induction motors use four motor leads. These leads are connected to field windings, two leads to a winding. The windings are connected in parallel if the voltage used is 110 V. or 115 V. The leads are connected in series if the voltage to be used is 220 V. or 230 V. Since the power is the product of the voltage times the amperage, the amperage flow using 220 volts is one half of the current flow using 110 volts.

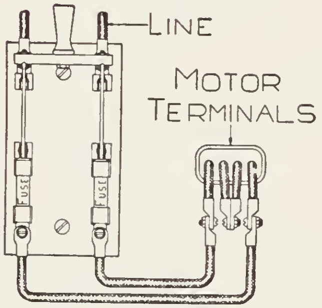
Fan motors and the like are generally wired for 110 V. to 115 V. only and they therefore have only two leads connected to the field windings. The maintenance of proper voltage at the motor terminals is absolutely necessary. Low voltage results in a rapid dropping of horsepower capacity of any motor, since the power that an alternating current motor will develop varies directly as the square of the voltage impressed at the motor terminals. Number 14 wires are of sufficient size to use with motors up to ¼ H.P. if the wires are a reasonable length. If

the wires exceed 50 feet, a No. 12 wire should be used. Loose connections also cause excessive voltage drop and are a fire hazard. Therefore, all the connections should be soldered or connected with Underwriters Approved mechanical clamps.

To illustrate how voltage drop affects the efficiency of a motor, the following example is typical: a 110-volt motor supplied with current at 95 volts will develop only about 75 per cent as much power as it would if supplied with 110-volt current. Figures 7-13 and 7-14 show the most common connections for single phase motors. Special motors requiring other connections are shipped with diagrams and instructions showing proper connections.



7-13. The method of wiring a 110-220 volt A.C. motor to a 110 volt A.C. line. (Century Electric Co.)



7-14. The method of wiring a 110-220 volt A.C. motor to a 220 volt A.C. line. (Century Electric Co.)

A 110/220 volt motor is connected to a 110-volt line through an across-the-line starter. The same connections are used to connect a 110/220 volt motor to a 110-volt line, etc.

A 110/220 volt motor is connected to a 220-volt line through an across-the-line starter. The same connections are used to connect a 110/220 volt motor to a 220-volt line, etc.

The field winding leads come out of the motor frame through a drilled hole. The wire is protected with a rubber, fabric, or plastic grommet. A small metal box is usually mounted over the leads to provide a protected place to house the electrical connections.

7-25. FUSES

Where a motor is started and stopped automatically and is installed in an out-of-the-way place or controlled from a distance, the use of a fuse having a rated capacity of not more than 100 per cent to 110 per cent of the rated ampere capacity of the motor is recommended. This fuse is of ample size to enable a motor to start and attain its rated speed fully loaded under normal conditions.

To permit the motor to develop its maximum rated capacity for short periods, and to enable it to start quickly under a heavy or inertia load, when the motor is being started and operated under the direct supervision of an attendant, a fuse may be used having a rated capacity of 125 per cent, but in no case larger than 150 per cent of the rated full load current of the motor.

The above applies to plug and cartridge type fuses approved by the National Board of Fire Underwriters. Experience shows that link and wire fuses quite often are unreliable.

An overload cut-out device consisting of a heating coil and ratchet

throw-out arrangement is often built into the thermostat. Also bi-metal overload devices may be placed at various important places in the unit. If these parts overheat for any reason, the circuit will be opened by the bi-metal snap switches. A plug fuse will not protect an overloaded motor adequately, because the fuse must be of enough capacity to withstand the starting load of the motor and if the motor draws this extra load long enough, it may burn out the motor.

7-26. REPULSION—START INDUCTION MOTORS

The repulsion-start induction motors have long been very popular where intermittent operation is needed such as in refrigerators, washing machines, oil burners, etc. The motor is an induction motor with a special winding in the armature to give it a high starting torque. The motor starts as a repulsion motor using brushes and the armature winding. As soon as it reaches a specified speed, the armature windings are shorted, the brushes are lifted from the commutator, and the motor operates an induction motor, Figure 7-9.

These brush lifting motors usually have radial commutators. Some of the motors do not lift the brushes but simply short circuit the commutator. Such motors usually have cylindrical commutators.

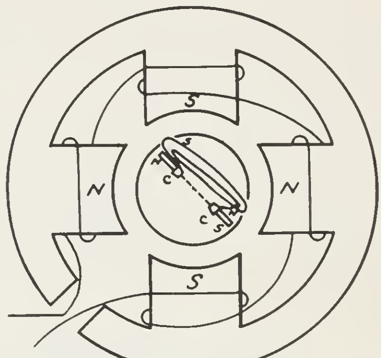
7-27. REPULSION—START INDUCTION RUN MOTOR PRINCIPLES

Refrigeration motors for the conventional units need a high torque at starting speeds to overcome the inertia of the refrigeration unit parts and to compress the gas from the low side pressure to the high side pressure.

Because the turning moment of a motor is a function of the magnetism, one must either strengthen the magnets or increase the number of magnets to increase the starting torque.

The repulsion start-induction motor increases the starting torque by increasing the magnetic strength of the rotor magnets.

The rotor is wound with a number of separate coils of wire and the ends of these coils are fastened to commutator bars. There is an equal number of brushes to the number of field poles. These carbon brushes complete the



7-15. A diagrammatic sketch of a repulsion start induction run motor C, commutator. The brushes that contact the commutator are grounded and complete the circuit between the two commutator bars.

circuit between the two commutator bars, and there is a current flow in the coil. Because this current flow creates magnetic poles, the brushes can be located so that these magnets can repulse the magnetism of the field poles and create torque, Figure 7-15.

When the motor reaches 1/2 to 2/3 of its standard RPM, a centrifugal weight shorts out the bars of the commutator, short circuiting the current flow in the rotor windings. Many motors connect this centrifugal device to the brushes also, and the brushes are lifted from the commutator bars at the same time the commutator bars are shorted.

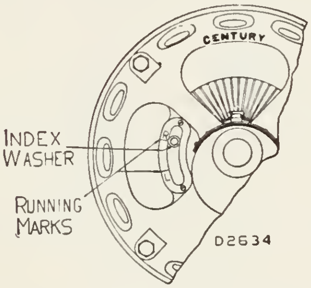
7-28. COMMUTATOR

The commutator bars are made of

copper, and mica is used as the insulation between the bars. There are two types of commutators, the radial type and the axial or cylindrical type.

One end of each bar is split, and the rotor winding wire is pinched in this slot and then soldered. The radial type commutator has the bars extending down into a hollow cylinder where a copper segment mechanism shorts the bars when it is moved against them. The axial or cylindrical type commutator has a short circuiting mechanism against the end away from the windings. In this type commutator, the brushes are not lifted but ride on the commutator at all times.

The commutator surface should always be straight and true. It must also be clean. Commutator cleaning stones are available for cleaning the commutator. A drop or two of carbon tetrachloride will also clean a commutator that has oil or grease on it. NEVER BREATHE CARBON TETRACHLORIDE FUMES OR ALLOW IT TO TOUCH THE SKIN.



7-16. The "Century" method of reversing the direction of rotation of their repulsion-start induction motors. (Century Electric Co.)

If the commutator becomes rough and burned, it should be cleaned by holding a piece of coarse (No. 1½ or 2) sandpaper against it with a flat block of wood so that the insulation between the commutator bars may be cut down to a level with the bars. (Never use emery cloth or emery paper on any commutator or brushes.)

Emery cloth must not be used, as the abrasive on the cloth is often a conductor; if it collects between the commutator bars, it may cause them to short circuit.

7-29. BRUSHES—BRUSH HOLDERS

The brushes are made of carbon. The carbon is available in various hardness. The correct brush is very important. The spring pressure on the brush must be enough to permit good electrical contact but not enough to cause rapid brush and commutator wear. The brushes are normally copper coated to help the electrical conductivity. The brush must fit its holder closely but it must be able to move freely. The full face of the brush should be in contact with the commutator. New brushes are quickly fitted by using sandpaper between the commutator and the brush with the sandpaper against the brush. A slight turning of the commutator back and forth will sand the brush to a form fit. The brushes should move freely but still fit closely enough to make good contact with the holders. If they do not move freely, they will not make good contact with the commutator during the period of starting. Any brush sticking in the brush-holders may be due to an accumulation of dirt and oil.

The brushes and brush-holders should be inspected occasionally to see that the brushes have not worn down to the point where they are so short that the brush-holder springs cannot press the brushes against the commutator. All brushes should be of the same length. The brush-holder should clear the commutator at least 1/8 inch.

7-30. HORSEPOWER CAPACITY

The motor will carry a greater load when running than the load it will bring up to speed at starting. However, such

loads should not be imposed, since they may cause the motor to be pulled out of step with the line, causing it to slow down and start again. Such action results in making and breaking the electric circuit in the armature. This causes burning and pitting and produces poor contact, which reduces the horsepower capacity.

If the motor is pulled out of step with the line, it is an indication to the operator that an abnormal overload has been applied, which should prompt him to relieve the motor of the overload. It is not good practice to overload a motor continually, since motors are usually designed to give the maximum efficiency at full load. A motor out of step with the line will emit a regular beat in addition to the usual hum.

7-31. DIRECTION OF ROTATION

Except for the reversible motor, the direction of rotation is changed by shifting the brush-holder. See Figure 7-16. This is accomplished by loosening the set screw at the side of the bearing housing on the commutator end of the motor, and moving the pointer to one of the lines or notches at the side of the slot. For right-hand or clockwise rotation, place the pointer at the line marked "R." For left hand or contra-clockwise rotation, place the pointer on the line marked "L." The letters "R" and "L" do not appear on some of the smaller motors. In those cases, move the pointer from the middle of the slot in the direction the armature should rotate and place it opposite the mark nearest that end of the slot. The pointer should be exactly on the line for the best results.

The method of reversing the motor varies with the manufacturer, but the fundamentals are the same. The direction of rotation of direct current motors is reversed by reversing the leads or wires which connect to the field windings.

7-32. REPULSION—START INDUCTION MOTORS ADJUSTMENTS

In the great majority of cases where the action of a motor seems to indicate that there is something wrong with it, the actual trouble lies outside the motor. Therefore, one should be prompted to inspect carefully the refrigerator machinery that the motor is driving to see that it is not imposing an overload upon the motor, due to the amount of work which the machine is doing, or due to having developed an unusual friction load in such machinery.

If the motor is belted to the compressor, see that there is sufficient oil in the bearings, that the shaft turns easily, that the shafting is in alignment, and that the belt is not too tight.

7-33. REPULSION—START INDUCTION MOTOR TROUBLES

See that the commutator is in good condition. Frequent starting, improper fitting of brushes, low voltage, or possibly some other reason will cause the motor to run on the brushes excessively which will roughen the commutator. To correct this, it is necessary to sand the commutator with coarse sandpaper (No. $1\frac{1}{2}$ or No. 2) to clean it and keep the insulation level with the commutator bars. Use a block of wood to hold the sandpaper so the high spots may be cut down to a level with the low ones. (Do not use emery cloth or emergy paper.) When the commutator is badly burned, the armature should be removed and placed in a lathe, where a slight cut should be taken off.

The brushes should fit well in the brush-holders, but still be free enough to allow the springs to press them

firmly against the commutator. Also, see that they have a good bearing fit against the commutator.

Be certain that the brushes are long enough. It may be that they have worn down so that the springs cannot force them to make good contact with the commutator.

Examine the setting of the brush-holder. The pointer on the index washer should be set exactly at one of the running marks on the index plate on the commutator end of the motor. The one running mark will give right-hand (clockwise) rotation and the other running mark will give left-hand (contra-clockwise) rotation facing the commutator end of the motor.

After the governor has acted, and the motor is carrying its load, the spring barrel ring should enter the bore of the brush-holder far enough so that the parallel motion fingers which are fastened to the brush-holder should not be closer to the commutator than 1/8 inch.

Examine the brush-holder and spring barrel to see that the spring barrel ring does not stick in the brush-holder. This would prevent the brushes from dropping back on the commutator when the motor stops.

Note how the motor is connected, whether for 110 or 220 volts, and see that it corresponds to the voltage of the circuit to which the motor is connected. Be certain the voltage is up to normal at the motor terminals all the time that the motor is starting and carrying its load.

Examine the governor mechanism. It may not operate satisfactorily due to the mechanism becoming clogged with dirt. An occasional drop of oil on the governor mechanism bearing points will do no harm.

The motor winding should be cleaned occasionally so that the dirt accumulated will not weaken or rot the insulation.

Storage of the motor in a damp place for some time may cause a sufficient amount of rust to accumulate to prevent satisfactory operation of the governor. Examine the short circuiting device. The short circuiting segments must make good contact between the commutator bars and the copper short circuiting ring; therefore, it may be necessary to occasionally clean the inside of the commutator. There will be no occasion for trouble at this point except for an abnormal accumulation of dirt or frequent imposition of loads in excess of the maximum capacity of the motor.

Test for short circuits in the armature. This may be done as follows:

1. Disconnect the motor from the apparatus it is driving.
2. Raise all the brushes off the commutator.
3. Close the switch which is used to start the motor.
4. Turn the armature slowly by hand. If there are any short circuits in the armature, the armature will apparently "stick" opposite each pole. The tendency to "stick" will be quite pronounced, and the armature will turn with a decided jump. If the armature turns freely, then the winding is all right.

Test for short circuits in the field winding. This may be done as follows:

1. Raise the brushes off the commutator.
2. Close the switch, thus throwing the field winding across the line. Leave the switch closed for a few minutes.
3. If there is a shorted coil, there will be unusual heating in this coil.

7-34. BEARINGS

Examine the bearings to see if they are worn. If the armature is striking

the metal of the field, this is a sure indication that the bearings are worn out and must be replaced. As the clearance between the armature and field varies from .015 in. to .030 in., dependent upon the size of the motor, a bearing should be replaced which shows any appreciable sign of wear. A heavy rumbling sound at the time of starting usually indicates that the bearing is badly worn although the armature does not quite touch the field.

The bearings are most commonly made of phosphor bronze and are pressed into the end brackets. Occasionally these bearings are locked in by a pin pressed through the bearing housing and into the bearing. The bearing must always be pressed inward to remove it. Care should be taken not to put an angular load on the housing when pressing the bearings out, as this will probably crack the housing. A special tool used to remove and install bushings or sleeve bearings is shown in Figure 7-17. After the bearing is pressed into the bracket when installing a new one, the bearing must be reamed. It is best to ream the two in line with adjustable reamers. The surface of the shaft in contact with the bearing must be perfectly smooth. A scored shaft may be repaired in a lathe with the use of a grinder in the tool post.

Hot bearings. The bearing on the commutator end of all motors will show a normal temperature rise in excess of the bearing on the pulley end because of a lesser forced circulation of air around it. However, the temperature rise should not exceed 40 C. or 72 F. above the surrounding atmosphere. Any one of the following causes may result in a hot bearing:

1. Oil which is too heavy.
2. Oil which is too thin. (Select a good grade of mineral lubricating oil which is not greatly affected by a change in temperature and does not foam or bubble too freely.)
3. Dirt or grit in the oil.
4. The belt may be too tight.
5. The pulley hub may be rubbing against the bearing.
6. The motor may not be properly lined up, causing the armature shaft shoulder to pull or be pushed against one bearing.

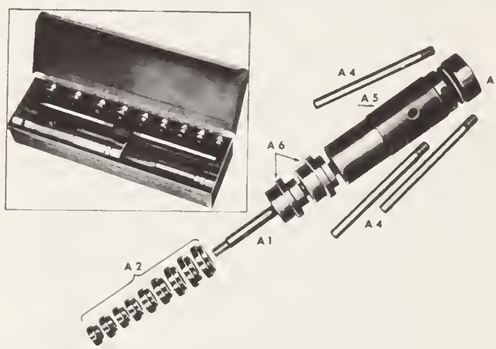
7-35. GOVERNOR AND BRUSH TENSION

This would indicate that one of the following is the cause:

1st. Low voltage. The voltage at the motor terminals must not be lower at any time than that for which the motor is wound, if the motor is expected to develop its rated capacity. (The power an alternating current motor will develop varies directly as the square of the impressed voltage.)

2nd. Overload. Frequently in cold weather poor oil will be so nearly frozen in motor shafts or other bearings as to cause a heavy friction load.

3rd. Frequency different from that for which the governor spring tension is adjusted. (Remember the frequency of the circuit governs the speed of any A. C. induction motor.) Occasionally



7-17. A motor bearing puller and installer. A1. Main shaft; A2. Different size bushing puller disks; A3. Take up nut; A4. Handles; A5. Main spacer; A6. Different size bushing socket spacers.
(Cleveland Sales Co.)

current that is supposed to be exactly 60 cycles, or some other particular frequency, is found sufficiently higher or lower to make a variation of as much as 5 to 10 per cent in motor speed.

If the motor is disconnected from the apparatus it is driving, and the governor acts properly after closing the switch, then "1," "2," and "3" is the probable cause of its failure to act when connected to its load.

Close the switch and note whether the speed of the motor decreases after the governor has acted; if it does, then loosen the spring barrel nut-one, two, or more turns as necessary. If that is regulated and if during the time the motor starting the voltage is maintained at 110 or 220 volts at the motor terminals (according to the connections), its failure to act is probably an overload; however, as a trial, the spring barrel nut may be loosened one or two turns, returning to its original position if it does not produce the desired results. This nut can be reached by removing the end bracket from the commutator end of the motor where the nut will be found on the armature shaft. It has a lock spring to prevent it from turning.

Failure of the governor to act under a load within rated capacity of the motor, with proper voltage at the terminals all the time the motor is being started, indicates that the frequency of the circuit is lower than that for which the governor is adjusted. It is therefore necessary to loosen the governor spring one or more turns. After the governor spring nut has been loosened and the governor operates, and if the motor does not hold its speed but drops back, then the motor is overloaded or the voltage is low.

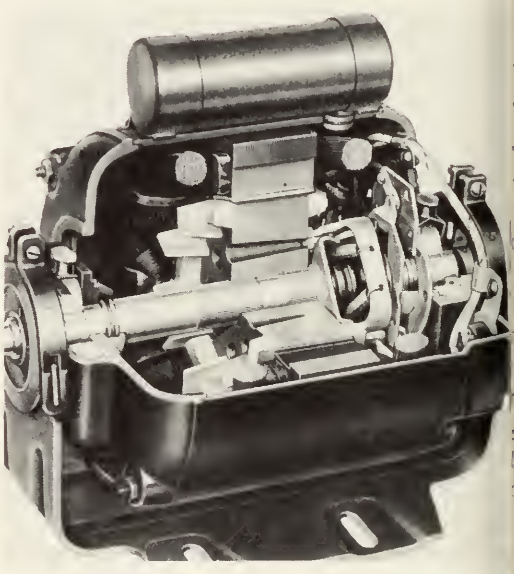
In some small motors, adjustment is not necessary. On these a non-adjustable spring collar is used instead of an adjustable spring barrel nut.

When removing an end bracket, mark it with a file or punch and also the body of the motor (stator) so it may be assembled in the correct order.

7-36. ARMATURE INSTALLATION

Whenever a new armature or a rewound armature is installed in a motor, it is always necessary to check the running marks, as slight variations in the windings make large changes in the position of the running marks. This check may be done as follows:

1. Loosen the screw in the index washer.
2. Turn the brush-holder until the point on the index washer is half-way between the original running marks (this point is called the dead point) and tighten the screw on the index washer.
3. Turn on the switch. (If the index washer is set correctly on the dead point, the motor will not start in either direction.)



7-18. A 1/2 H.P. capacitor motor quarter sectioned. Note the flexible mounting. (Wagner Electric Corp.)

4. If the motor starts in either direction, open the switch, move the index washer in a direction opposite to the direction in which the armature turned, tighten the screw on the index washer, and try it again.
5. When the true dead point (the point at which the motor will not start in either direction) is found, mark it with a pencil or a piece of chalk.
6. The new running marks should then be marked on the index plate in such a position that they are the same distance apart as the original running marks and the new dead point is exactly half-way between them.
7. Set the point on the index washer exactly on one of the new running marks.

7-37. GOVERNOR ACTION

Frequent governor action indicates one of the following causes:

1st. The most probable cause is that the tension of the governor spring is not correct for the frequency of the circuit on which the motor is installed; hence the motor is unable to reach such a speed before the governor acts as will allow it to bring its load up to full speed which is governed by the frequency of the circuit after the governor has acted. This trouble may or may not be accompanied by blowing of the fuses. Provided the proper voltage is maintained at the motor terminals all the time the motor is starting, the remedy is to tighten the governor spring nut one or more turns as may be necessary. This nut can be reached by removing the end bracket from the commutator end of the motor, where the nut will be found on the armature shaft. It has a lock spring in it to prevent it from turning.

2nd. Change of frequency may be caused by change of generators or by poor regulation of engine or turbine. It is not infrequent that the current is supposed to be exactly 60 cycle or some other particular frequency, when on investigation it is found that the speed of the generator is sufficiently higher or lower than it should be to give that frequency, to make a variation of 5 to 10 per cent.

3rd. Change of voltage at the motor terminals.

1. Sudden change of load on generator.
2. Frequent starting of large motors on the transmission line.
3. Heavy varying load on motors on same circuit.

4th. Low voltage. Causes:

1. Wire which is too small.
2. Transformer which is too small or has poor regulation with an induction load.
3. Loose connection, either at the motor terminals or at the switch, or in the line.

5th. Overload.

6th. Poor contact between short-circuiting segments and commutator bars, resulting from an unusual accumulation of dirt.

7-38. TEMPERATURE

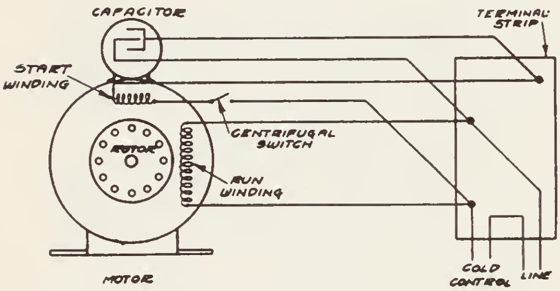
Do not use the hand to judge the temperature of a motor. Use a thermometer and check against the allowable temperature rise shown on the name plate.

The temperature of the motor should not rise more than 40 C. (72 F.) over the room temperature. This means an average maximum temperature of approximately 150 F.

7-39. CAPACITOR TYPE MOTOR

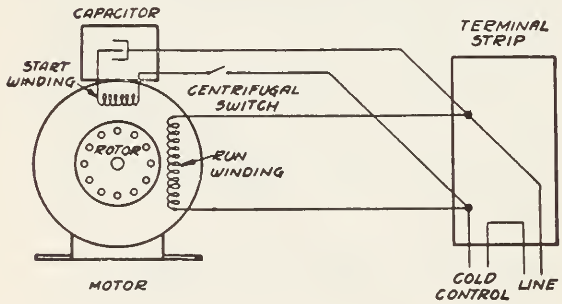
Domestic refrigerators frequently use a different type of motor from the

repulsion-start induction motor. Since 1933, this type of electric motor has become very popular. It is called the capacitor type, and the name is derived from the use of a capacitator or of a condenser and a transformer, Figure 7-18. It becomes a two-phase motor when starting and reverts to single phase when it has gained 75 per cent of its full speed. The capacitator is used to change the phase angle of the current in the starting winding to produce two-phase electrical characteristics when starting.



7-19. Electrolytic capacitor start induction run motor. (Stewart-Warner Corp.)

The mechanical construction of the motor is quite similar to the induction motor; that is, the external appearance, the mountings, and the bearing design is conventional both as to size and lubrication. However, instead of using a starting winding in the armature, the capacitor type has a condenser mounted on top of the motor, which is connected in pairs to a centrifugal switch built into the motor and to a starting winding in the stator, Figure 7-19.



7-20. A permalytic capacitor start-induction run motor. (Stewart-Warner Corp.)

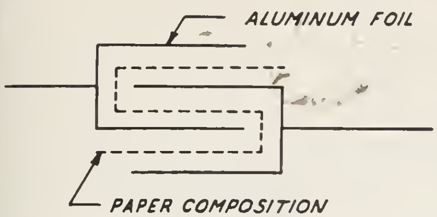
The operation of the mechanism is quite simple. When the motor starts, the centrifugal switch is closed, making the current pass through both the starting winding and the running winding. The starting winding is connected in series with a capacitor which puts the electrical surges in the starting winding out of step with those of the running winding. This produces a temporary two-phase motor and gives a very high starting torque. When the motor reaches approximately 75 per cent of its rated speed (1200 r.p.m.) the centrifugal switch opens disconnecting the starting winding. The motor, however, continues to run, but now as an induction motor.

These motors are commonly called capacitor-start induction run motors. The capacitor may usually be found in a steel cylinder which is mounted on top of the motor. It has two terminals, one to be connected to the centrifugal switch lead and one to the starting winding lead, Figure 7-20.

7-40. CAPACITOR START MOTOR PRINCIPLES

The least complicated method to produce starting torque is to convert the single-phase motor into a two-phase motor during the starting period by using a capacitor. The dry type capacitor consists of two sheets of conductor metal separated by an insulator, Figure 7-21. Due to the operating principle of a condenser or capacitor in an alternating current line, the capacitor is charged during the build up of the voltage and current by the surge of power in the line. Then, during the decrease in current flow in the power line, the capacitor discharges causing

another power surge in the motor starting windings, Figure 7-22.



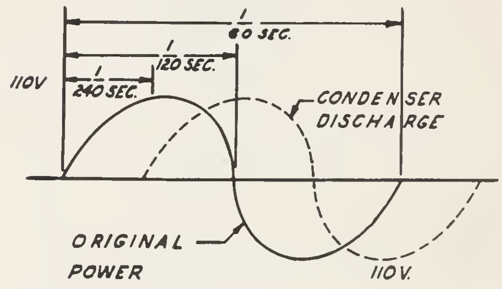
7-21. Elements of capacitor design. The paper composition is usually rolled or folded between the two separate sheets of conductor foil providing a large capacitor area in a relatively small space.

7-41. CAPACITOR START—CAPACITOR RUN MOTOR PRINCIPLES

This motor usually uses an oil sealed or insulated capacitor. It also uses a step-up transformer. When the motor is started, the capacitor turns the motor power surges into two-phase power and a higher voltage is also imposed on the starting winding. After the motor reaches two-thirds or three-fourths of its rated speed, the relay reduces the auto transformer to a step-up of only 200 volts, but the capacitor is left in the circuit. This action produces a two-phase motor at all times and results in a very efficient motor. It is used considerably in the larger hermetic units used in commercial systems, but its first cost and maintenance has practically eliminated it from the domestic field, Figure 7-23.

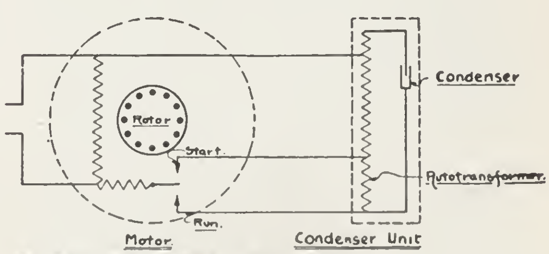
7-42. CAPACITOR MOTOR TROUBLES

The troubles encountered in the capacitator type motor are few, and they deal mainly with the mechanical condition of the motor. Outside of the two electrical troubles encountered in electric motors, these two troubles are: there is a possibility that the centrifugal switch used for connecting and disconnecting the condenser may become worn, in which case a replacement is necessary; also, an open or short circuit may occur in the field windings, in the condenser, or in the auto transformer. The latter ones naturally necessitate a replacement of the motor, while the first trouble may be repaired by installing a new switch. The mechanical troubles are practically identical to those encountered in the repulsion-start induction motor, involving bearing wear, end play, excessive vibration, orientation of the motor to the compressor, and the air gap between the rotor and stator.



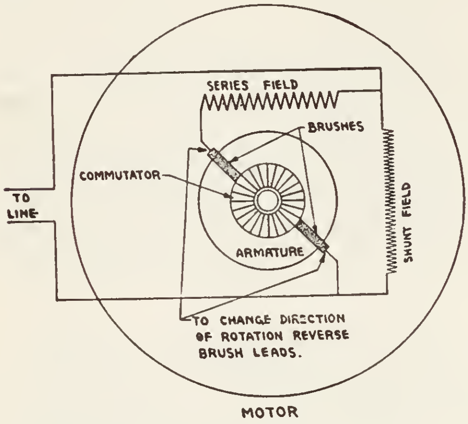
7-22. The effect of a capacitor on the power flow in a single phase circuit.

Very frequent starting of the capacitor motor results in overheating; the condenser and the insulation may fail. If the motor will not start but simply has the characteristic A. C. hum until one spins the pulley and then the motor starts satisfactorily, it is a sign that the capacitor or the centrifugal switch points have failed. It is an easy opera-



7-23. The wiring diagram of a full capacitor motor. (Norge Sales Corp.)

tion to substitute a good capacitor for the questioned one. If the motor still will not start, the trouble is probably in the centrifugal switch.



7-24. Wiring diagram of a compound direct current refrigerator motor.
(Norge Sales Corp.)

7-43. DIRECT CURRENT MOTORS

Certain localities using D.C. power must have direct current motors for their refrigerators. These motors are compound wound and are constructed mechanically very similar to both the capacitator and repulsion-start induction type, Figure 7-24.

Compound wound windings are two field windings; one is in parallel with the armature windings, and one field winding is in series with the armature windings. Because D.C. is used, the field poles always have the same magnetic polarity, and as the same D.C. is going through the armature coil, the armature magnetism is positioned to cause a turning torque in the armature. The series field is used to keep the motor speed constant. If the speed attempts to change, the series winding strength builds up to increase the r.p.m. or weakens to reduce the r.p.m. Note that one has only to reverse the brush leads to reverse the direction of these motors (it reverses the armature magnetic polarity).

The possibilities for wear are a little greater in the direct current motors than in the others because of the armature design. This design necessitates constant contact of the brushes against the commutator, giving rise to the following possible troubles: dirty commutator, worn brushes, high mica, shorted armature, squeaky brushes, etc. In general, all of the brush and commutator troubles are treated as in the case of the repulsion-start induction motor.

7-44. RADIO INTERFERENCE

Some refrigerators will give a slight amount of radio interference in the average installation. This will usually amount to a slight snap in the radio at the instant the refrigerator stops, and should not be more noticeable than the turning off of a light. This may be eliminated some by grounding the frame of the motor to a water pipe or by placing a condenser between the frame of the motor and a convenient ground. In general, the normal interference is not disagreeable and need not be given any attention.

Excessive radio interference of a continuing nature when the refrigerator motor operates or when it starts indicates a loose electrical connection or some fault in the motor's starter mechanism such as worn brushes, badly pitted commutator, or loose connections. The particular trouble can be easily determined by a careful examination of the motor.

Occasionally a static charge will be built up on the belt of a belt-driven compressor. The discharge of this charge will cause radio interference. If the motor and compressor are grounded together, this annoyance will be eliminated.

Room Tempera-ture	Inside Tempera-ture	Dif.	A Cap. lb./day	A Power kw.hr. ton/day	B Cap. lb./day	B Power kw.hr. ton/day	C Cap. lb./day	C Power kw.hr. ton/day	D Cap. lb./day	D Power kw.hr. ton/day
90	50	40	297	74	116	116	95	144	94	168
80	45	35	337	64	116	106	95	133	104	136
70	42	28	336	65	104	92	119	112	123	108
90	55	35	282	80	147	102	104	127	80	166
80	50	30	310	78	171	98	110	125	98	138
70	45	25	334	66	161	96	102	122	100	136

7-25. Capacity and power consumption of four domestic refrigerating units with 1/4 H.P. motors. A and D Methyl Chloride; B and C Sulphur Dioxide.
(American Society of Refrigerating Engineers)

Wire No.	Diameter of Wire in inches	Ampere Capacity Rubber Insulated	Ampere Capacity Other Insulation
18	.040	3	5
16	.051	6	10
14	.064	15	20
12	.081	20	25
10	.102	25	30
8	.128	35	50
6	.162	50	70
4	.204	70	90
2	.258	90	125

7-26. Wire sizes. National Board of Fire Underwriters' wire recommendations.

'-45. STANDARD MOTOR DATA

The split phase motor involving the ·epulsion-start induction type and the :apacitor type is obtainable in 25, 30, ·0, 50, and 60 cycles and uses either 10 or 220 volts. The 30 and 60 cycle notors run at 1750 r.p.m. while the 25 .nd 50 cycle motors have a speed of 425 r.p.m. The 40 cycle runs at a peed of 1150 r.p.m. The D.C. motor oltages are 32, 115, and 230 volts nd run at a speed of 1725 r.p.m. These notors are supposed to run continously with a temperature rise not xceeding 40-55 C. which is approxinately 90 F. above room temperature, 'igure 7-25.

Compensation for reduced motor peeds is usually made in pulley sizes. Direct connected compressors must have ample displacement at the reduced speeds, or special compressors of greater displacement must be used with odd cycle motors.

The wire size used in the refrigeration mechanism is very important. If the wire is undersize, it will heat up and may eventually cause a fire, and it always adds an unnecessary resistance to the flow of electricity, Fig. 7-26.

The efficiency of small motors is only 50 per cent to 60 per cent; therefore, they consume nearly twice as much current as they should theoretically. A 1/6 H.P. motor which should theoretically use only 124 watts or 1 1/4 amperes will be found to need approximately 2 1/2 to 3 amperes, Figure 7-27.

Motor Size H.P.	Normal Input Watts	Inside Volume, Cabinet Ft.	Ice Melting Capacity, lb./day
1/10	145	4	50
1/8	160	5.5	70
1/8	160	6	70
1/6	200	5.5	92
1/6	200	7.5	92
1/6	200	10	112
1/6	200	13	112
1/6	200	17	112
1/3	340	13	200
1/3	340	17	200
1/2	475		333

7-27. Energy required for domestic refrigerator. Hermetically sealed machine, installed in cabinet. (American Society of Refrigerating Engineers)

In making electrical connections to a domestic refrigerator, it is always preferred that the thermostat which is installed in the circuit be hooked in the live wire line of the circuit. This live wire in the alternating current circuit is easily recognized by the fact that if a trouble lamp were hooked to one of the lines and then grounded to a very good ground such as a water pipe, the lamp would light if that particular wire happened to be the live wire of the two.

Room Temperature F.	Relative Ice Melting Capacity
60	140
70	105
80	100
90	95
100	89
110	84

7-28. Capacity and room temperature. Average for actual refrigerators in use. (American Society of Refrigerating Engineers)

The other wire is called the ground wire of the circuit, and it should be run directly to the motor. If a trouble lamp is not available, an AC voltmeter will serve the same purpose, Figure 7-28.

Power consumed by a domestic refrigerator is shown in Figure 7-29. Note that August is the month using the most energy for refrigeration and at 3 cents per Kw. hr. the cost would be $1.68 for the month. The total cost per year based on 542 Kw. hr. would be $16.26, which is a very reasonable charge compared with the utility of the unit.

7-46. HERMETIC MOTORS (MECHANICAL ASPECTS)

Hermetic motors used in hermetic refrigerators are of the induction type. These motors have two field windings (stator) and induce magnetism in the rotor. Two types of induction motors are used:

a. The split-phase type
b. The capacitor type

Several problems required solution before the sealed-in motors were able to perform satisfactorily.

a. Special cooling provisions had to be incorporated.
b. Wire insulation had to be made resistant to chemicals in the refrigerant and the oil, particularly in the presence of moisture.
c. Perfect alignment of the stator, rotor, and compressor were required.
d. Electrical connections through the sealing dome had to be electrically perfect and leak-proof

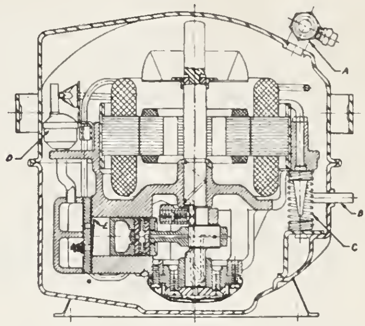
Time of Day	Refrigerator Watts
oon	58
2:00 P.M.	62
4:00	62
6:00	62
8:00	66
0:00	60
idnight	64
2:00 A.M.	56
4:00	54
6:00	52
8:00	54
0:00	54
verage Load	59
aily Load Factor	87

Time of Year	Refrigerator kw.hr./month
anuary	34
ebruary	40
arch	42
pril	46
ay	46
une	46
uly	55
ugust	56
eptember	53
ctober	52
ovember	43
ecember	39
Total	542

-29. Average electric load from 1000 homes with refrigerators, (Watts/House)
(American Society of Refrigerating Engineers)

The motors are cooled by several ethods. One successful method is press the stator into the dome and ien put cooling fins on the dome. nother method cools the motor by unning oil over the motor windings hile the unit is running. For several ears the older Norge refrigerator assed partly cooled condenser reigerant around the motor housing to id in cooling the electric motor.

Motor windings (wires) have preented many electrical and mechanical roblems to the refrigeration engineer. These windings must be compact, must be easily cleaned and dried, must be chemically inert, and must stand considerable overloads without burning out or shorting. The first successful windings had special long fibre bleached double cotton covered insulation and nothing else. All other insulations at



7-30. A hermetic compressor and motor cut-a-way. A. Suction service valve; B. Discharge line; C. Mounting spring; D. Intake muffler; E. Intake valve.
(Tecumseh Products Co.)

that time would deteriorate in the presence of the refrigerant, especially if small amounts of moisture were present. Several companies have now developed special wire coatings (usually enamel) that are very satisfactory insulations for most of the refrigerants used today.

The alignment of the electric motor parts and the compressor is usually accomplished by using a common surface on the motor stator to which the compressor body is bolted. Aligning dowel pins or shoulders must be very accurately matched to produce maximum accuracy and therefore operating efficiency and quietness.

Figure 7-30 shows a hermetic motor installed while Figure 7-31 shows the stator and rotor of a hermetic motor.

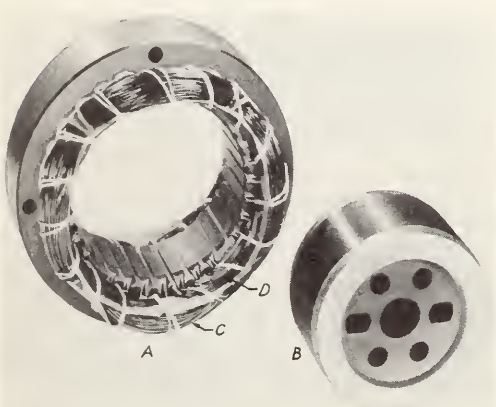
Most of the service connections for checking pressures, purging, etc., are mounted on the compressor dome.

These connections require the use of a valve adapter set. See Chapter 17.

7-47. HERMETIC MOTORS (ELECTRICAL CHARACTERISTICS)

The design characteristics of the electric motors used in the hermetic machines depend to a great extent on whether the unit starts under load or whether it starts under a no-load or balanced pressure condition.

However, the basic operation of the motor is the same as for open-type motors. Brushes and/or open points cannot be used in the hermetic motor, because the arcing would gradually disintegrate the refrigerant and the oil in the unit. Therefore, an external



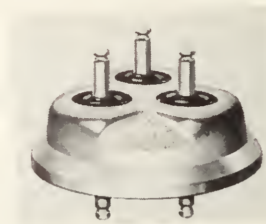
7-31. A 1/4 H.P. split-phase hermetic motor. A. Stator; B. Rotor; C. Running Winding; D. Starting Winding. (Wagner Electric Corp.)

means must be used to disconnect and connect the various windings. Finally, all torque must be developed by induction only.

One of the very important objectives in the alignment problem is to produce an equal and absolutely minimum gap between the rotor and the stator of the motor. An appreciable air gap between these two decreases the motor efficiency, and any unequal air gap produces a motor hum that can be loud enough to produce noise complaints. Note in particular that many condensing units are mounted on springs inside the dome.

The electrical terminals, which carry the circuit through the dome, must be electrically insulated from the dome, and they must also be leak proof.

Many terminal designs have been used. Metal terminals that clamp



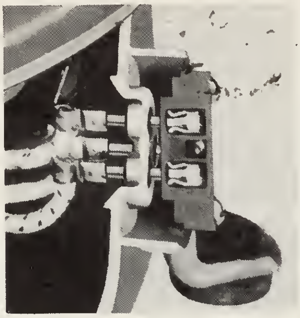
7-32. A metal terminal, fused to glass, and the glass i turn fused to a metal disc as used for insulating and lea proofing the electrical connections for hermetic motc terminals. (The Fusite Corp.)

against the housing using syntheti rubber insulators and gaskets are used Also metal terminals fused to glas which in turn is fused to a metal dis makes an assembly that can be welde to the hermetic dome, Figure 7-32. Th terminals which must be leak proo after thousands of cooling and heatin contractions and expansion cycles must also have a high insulating value A fused glass multiple terminal install ed is shown in Figure 7-33. The wir terminals are spring clips that tightl clamp on the hermetic terminals.

Replacement terminals are used b many service men. These replacemer terminals use synthetic rubber gasket to make a leak-proof joint.

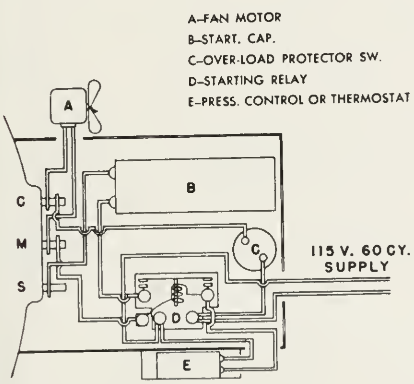
The higher starting torque require (turning effort) for those units whicl start under load necessitates the use o larger conductors in the starting circuit. This required starting torque is usually obtained by using one of severa electrical devices. Usually, manufacturers attempt to provide starting pow-

er equal to twice the running power (torque). In other words, we attempt to have a 1/6 H.P. motor produce 1/3 H.P. during starting. The attempt is also



7-33. A metal-fused glass hermetic electrical terminal installed. The wires are connected by spring loaded clips. Note the metal housing used to protect the terminals from abuse.
(The Fusite Corp.)

made in some cases to put more frequent power surges into the motor during the starting time. Likewise, various methods are used to shut off the special starting devices after the motor has approached its full speed.



7-34. A schematic diagram of a capacitor start hermetic unit wiring system.
(Servel, Inc.)

7-48. HERMETIC MOTOR CONSTRUCTION

The motors are built as sturdy as possible. Because an overheated motor or undersized bearing would necessitate a major or complete overhaul of the unit, special care is taken to put very high safety factors into the motor construction.

Much experimenting, designing, and research has produced the present-day motors. These motors produce a maximum torque with a minimum current draw and a minimum temperature rise. The development of more efficient laminated field poles and rotor steels has done much to improve these motors.

7-49. HERMETIC MOTOR TYPES

There are four types of hermetic motors:

a. The Split-Phase Motor
b. The Capacitor Start Motor, Figure 7-34.
c. The Capacitor Start, Capacitor Run Motor
d. The Auto-Transformer Motor

The first two types are in most use at present. The capacitor start, capacitor run type is not in great use, because even though an oil type capacitor is used instead of the dry or electrolytic type, the insulation is likely to break down due to overheating. Cost is also a factor. The cost of the auto-transformer and the complicated and expensive relay also has eliminated this type of unit from the market except in large hermetics.

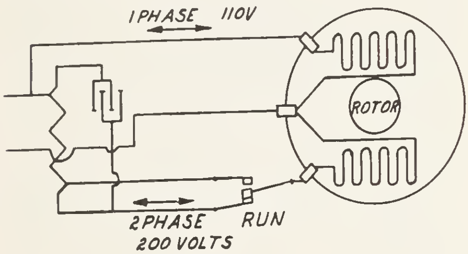
The principle of operation and the construction of all of these motor types have already been explained in previous paragraphs.

7-50. THE SPLIT-PHASE INDUCTION MOTOR

This motor is the basic type motor for all the hermetic condensing units in use today. It has the advantage of relatively low cost, since no extra devices are needed. The principle of operation is simple. There are two

windings, a running winding and a starting winding. These windings are made into four coils each with the starting winding positioned an actual 45 degrees around the stator from the running winding. This positioning puts the starting winding 90 electrical degrees from the running winding.

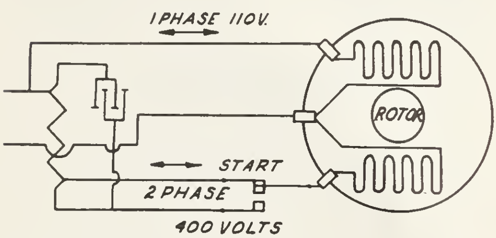
The smaller wire is used in the



7-35. A capacitor start auto-transformer unit with the relay in the "running" position.

starting winding. This smaller wire slows the current and builds up magnetism more slowly than the running winding. When the unit control thermostat points close, current goes through the larger windings a little faster. The starting windings follow very quickly, and its magnetism is a little slower building up than the running winding. This slower build up causes a shift or side movement to one side in the field, thereby producing a twist or torque effect on the rotor.

The current tries to go through both windings with equal speed, but the resistance of the finer (starting) winding is a little greater than the running winding. The magnetism of the running winding therefore builds up a little sooner and induces an opposite magnetism in the rotor. Very shortly after this, 1/1000 of a second or so, the starting winding builds up to its maximum magnetism and this magnetism attracts the induced magnetism in the rotor and causes a twist in the rotor. The starting winding is continued in use until the motor reaches at least 1/2 of its full speed. From this speed up to the full speed of the rotor the 60 cycle time interval and the four pole stator will automatically run the rotor at its 1800 r.p.m. This 1800 r.p.m. is always true of a four pole, 60 cycle motor, because the rotor must travel from one pole to the next in one change of the current. In a 60 cycle circuit the current changes direction each 1/120 seconds. This time means the rotor makes one revolution (four poles) in 4/120 seconds or 1/30 of a second. In one minute or 60 seconds, therefore, the motor will turn 60 x 30 or 1800 revolutions. Actually there is a slight slippage of the rotor in its magnetic field, and these motors will actually run 1750 to 1775 revolutions per minute. The speed is slightly different for different motors, but for any particular motor it will be constant as the slippage will be constant.

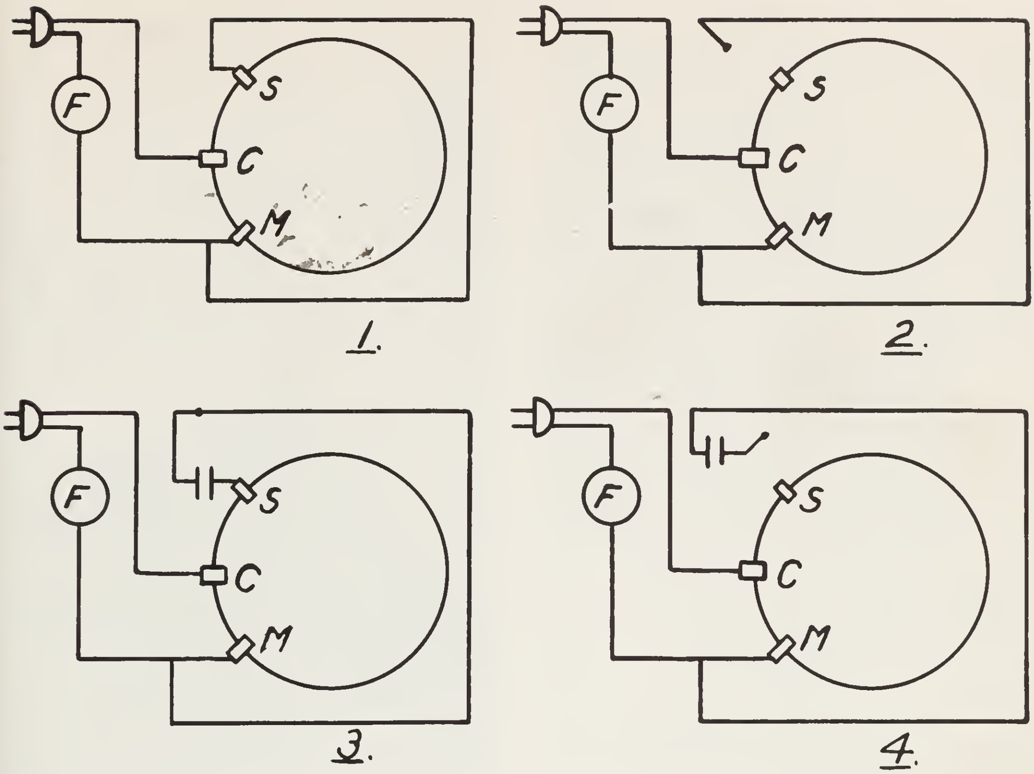


7-36. A capacitor start auto-transformer hermetic motor with the relay in the starting position.

These motors are used on small units 1/10, 1/6, 1/4 H.P. that have no starting load (capillary tube) or have an electric, mechanical, or hydraulic unloading device.

The hydraulic device is usually a gravity valve that unloads the compressor until the compressor builds up an oil pressure as it turns over while starting. The oil pressure must build up strong enough to lift the weight valve and close the by-pass port.

The mechanical unit consists of a centrifugal unit that unloads the compressor by a by-pass until the rated speed of the compressor moves the



7-37. Manually starting a stuck unit using normal voltages. 1 and 2 without a capacitor; 3 and 4 with a capacitor in the starting circuit.

centrifugal device enough to close the by-pass.

Several variations of the split-phase motor have been used in hermetic mechanisms. The simplest type disconnects the starting winding completely after the motor reaches approximately 2/3 or 3/4 of its rated r.p.m. Another type uses a two-stage transformer that starts on one step of the transformer and then switches to the other step by means of the relay as the motor reaches its design speed. This type of starting winding with its auto-transformer is usually called an auxiliary winding instead of a starting winding, because it is in use all the time the current is flowing, Figures 7-35 and 7-36. This auto-transformer is used when the motors start under load.

7-51. SERVICING HERMETIC MOTORS

The servicing of hermetic motors may be divided into two major sections: external servicing and internal servicing. Most of the hermetic motor troubles are external, or, are in the wiring or in the motor control devices. It is very important to determine exactly where the electrical troubles are before deciding the motor is at fault.

Furthermore, it is essential that any external trouble be remedied as soon as possible, because this minor trouble may eventually cause the motor to fail.

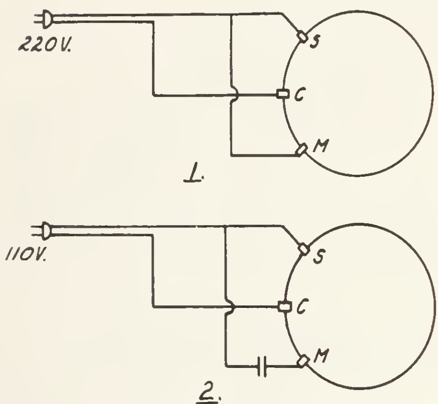
7-52. STARTING A STUCK MOTOR

Occasionally a unit may be found that will not start, even though all the

electrical tests indicate a unit in good condition. This stuck condition may be caused by the unit standing idle for a considerable time, a particle of dirt, or some electrolytic plating may have taken place. A more than normal amount of liquid refrigerant in the compressor may also bind the unit. Three methods are recommended to break loose a stuck unit.

a. Connect the power line direct to the motor connections eliminating the starting relay, Figure 7-37.

b. By using above-normal voltage, such as 220 volts on a 110-volt circuit, may break it loose. This method can only be used for a short period of time, Figure 7-38-1.



7-38. Starting a stuck compressor. 1. Using above normal voltages; 2. Using a capacitor in series with the running winding.

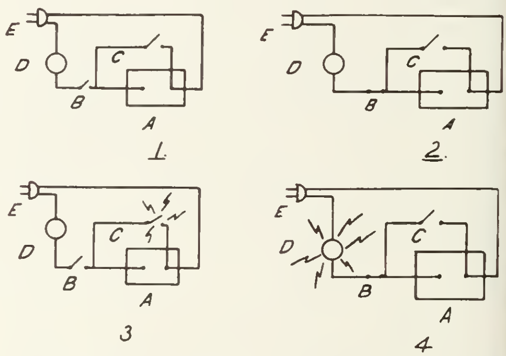
c. By reversing the unit, that is, making it run backward. This reversal rotation may be done by putting a capacitor in series with the running winding. Figure 7-38-2.

It is of utmost importance to be continually on the alert to avoid handling high voltage circuits and that one short circuits capacitors to discharge them before handling.

7-53. SERVICING THE CAPACITOR

Most units have one capacitor, the starting capacitor, but some have two capacitors; either one starting capacitor and one running capacitor or two capacitors connected in parallel for additional capacitance. The starting capacitor is connected in series with the starting winding and is usually connected into the circuit between the relay and the starting winding terminal of the motor.

The simplest test of a capacitor is to substitute a good capacitor for it; then if the motor operates, it is known that the old capacitor is faulty. Another way to check a capacitor is to disconnect it from the circuit and connect the proper voltage power to its terminals (be sure a fuse is in the circuit); then, short the terminals of the capacitor. If the capacitor is good, it will spark after two or three tries to charge it. If it has an open circuit, no charging, therefore, no sparking will take place. If it is shorted or grounded, the fuse will blow. A capacitor testing



7-39. Testing a capacitor. A. Capacitor; B. Charging switch; C. Shorting switch; D. Fuse or circuit breaker; E. Plug for 110 volts; 1. Switches open; 2. Charging switch closed; 3. Good capacitor; 4. Shorted capacitor.

stand or device in a shop should use a circuit breaker rather than a fuse, to save costs. Figure 7-39. A is the capacitor, B is the charging switch, C

is the shorting switch, D is the fuse or circuit breaker, E is the power connection or plug. Commercial models are obtainable at refrigeration supply houses. In (1), the tester is connected to the terminals of the capacitor A with spring clips, rubber covered. Both switches B and C are open. Some models have button switches similar to door bell switches that are spring loaded to stay open. In (2) the charging

7-40. A capacitor test unit and analyzer. This unit will detect all hermetic and open motor troubles and can be used to reverse the motor.
(Airserco Mfg. Co., Inc.)

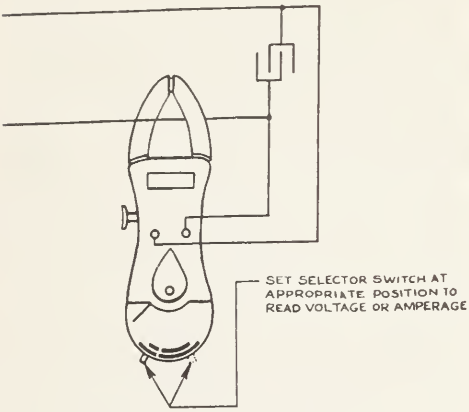
switch B is closed momentarily; just touch it. Note that switch C stays open. If the capacitor is shorted, the fuse or circuit breaker will blow (4) D. If nothing happens, then proceed as in 3. With the switch B open, touch the shorting switch. If the capacitor is good, the switch will spark. If it does not spark the first time, try it three or four times before scrapping the capacitor. Figure 7-40 illustrates a commercial model of a capacitor tester. These testers are sometimes equipped with a neon light to indicate the discharge (in the circuit) and they also use a voltmeter to determine the efficiency of the discharge.

Important: Never put your fingers across the terminals of a capacitor as it may be charged and give you a shock. Always short it with a wire first before handling it.

A capacitor must be accurately sized to the motor and the motor load. It is general practice to permit a 25 per cent overload capacity, i.e., a 125 mfd. can be used for a 100 mfd. capacitor, but an undersized capacitor should never be used. If it is at all possible, use an exact replacement capacitor. The make, model and model number are usually placed on each capacitor. If this information is unavailable, or if an emergency capacitor must be used temporarily, there are several ways to determine the proper size unit. One of the quickest methods is to cut the temporary capacitor in the circuit and if it brings the unit up to running speed and the relay operates in 3 seconds, the capacitor is very nearly correct. A better method is to use a specially designed capacitor selector unit, Figure 7-41. This selector has a variable capacitance and more mfds. are put in the circuit (in series) until the voltage

7-41. A capacitor selector unit in operation.
(Aerovox Corp.)

reading is reached for the unit. The capacitance registered on the selector indicates the capacity of the capacitor to be put in the circuit.



7-42. Measuring the capacity of a capacitor.
(Pyramid Instrument Co.)

7-43. A compact ammeter-voltmeter that is quickly connected to a refrigeration electrical circuit for checking the electrical flow.
(Pyramid Instrument Co.)

Another method that may be used to check the capacity of a capacitor is shown in Figure 7-42. The capacitor is connected to a double-fused line and the voltage leads of the meter are connected across the capacitor. The ammeter reading is obtained by the heavy probes around the wire.

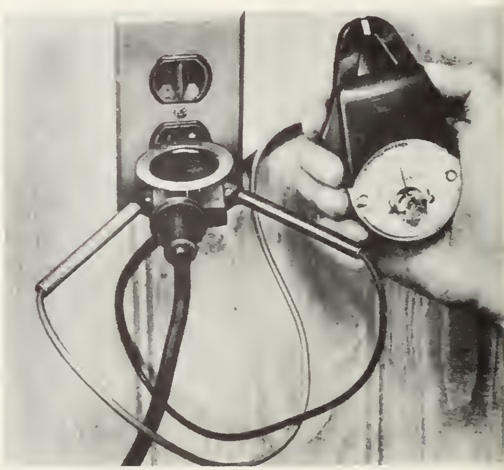
There are two types of capacitors, the electrolytic or dry type and the oil

7-44. Taking the amperage reading of refrigerating unit.
(Pyramid Instrument Co.)

type. These capacitors may all be tested in the same way. However, the oil type is usually used only as the continuous operating type (capacitor run type of motor) and is usually of much smaller mfd. capacity.

Some of the capacitors have mechanical connectors (machine screws) while some have solder-type leads. It is necessary to carry a small electric soldering iron to facilitate connecting these latter units.

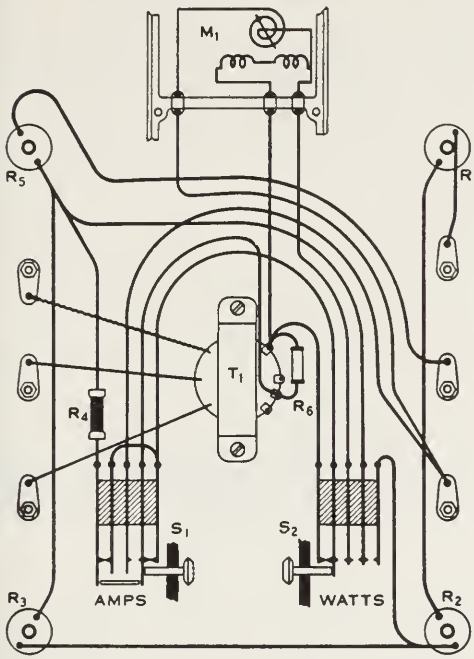
There are some hermetic testing units or analyzers that are used to



7-45. Taking the voltage reading of a refrigerating unit.
(Pyramid Instrument Co.)

check capacitors, motor windings, relays, overload cutouts, etc. Some are equipped with light indicators while some use voltmeters, ammeters, ohmmeters and wattmeters.

A very popular instrument for checking the electrical flow to a refrigerator unit is shown in Figure 7-43.

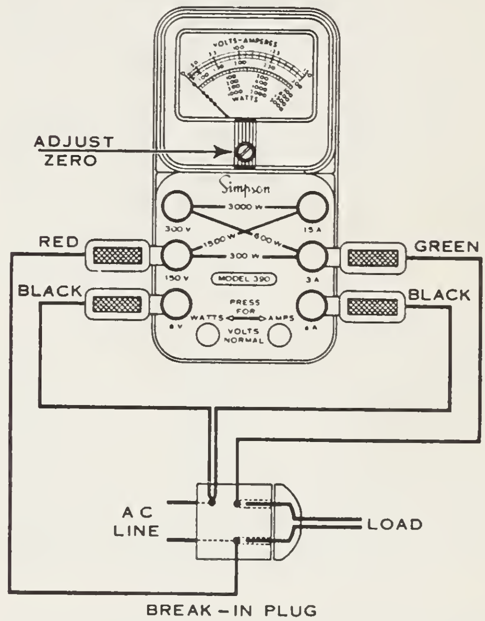


7-46. A combination volt, ampere, and watt meter. (Simpson Electric Co.)

The ammeter scale is at the top and reads from zero to 25 amperes. This instrument is quickly connected into the electrical circuit; reveals the current flow and the voltage in the appliance power circuit. The voltmeter has two scales 0, 125 or 150 and 0-250 or 600 volts. Figure 7-44 shows the instrument being used as an ammeter while Figure 7-45 shows how the instrument is connected to obtain the voltage readings.

7-54. WATT READINGS

One of the means to determine the condition of the motor-compressor unit



7-47. A combination volt, ampere and watt meter connected between the AC line and the load. (Simpson Electric Co.)

is to observe the wattage consumption of the unit. An instrument which is used to obtain the voltage, amperage and wattage values is shown in Figure 7-46. Figure 7-47 shows how to connect the wattmeter into the wiring circuit.

The meter will give three wattage readings:

1. Over swing reading.
2. Combined starting and running winding reading (of only 1 to $1\frac{1}{2}$ seconds duration).
3. The running winding reading.

When the thermostat contacts close, the wattmeter pointer will swing to the right (3), and then it will quickly move back to the combined reading (2). Then in one second the pointer will fall to the running winding reading (1) only.

If the starting winding circuit is open, the wattmeter pointer will swing to the right and then move back to the running winding value only. This action indicates a bad relay or starting winding. The overload safety cut-out should open the circuit in a few seconds (2 to 3 seconds).

If the pointer swings to (3) and then to (2) and after a few seconds the pointer

Motor H.P.	Running 70F.	Running 110F.	Watts (110 Volts) Combined Running and Starting	Stalled Running
1/16	66	100	1000	375
1/9	117	160	1800	740
1/8	108	163	1850	743
1/7	160	218	1850	970
1/5	242	295	1800	1450
1/4	235	320	2300	1250

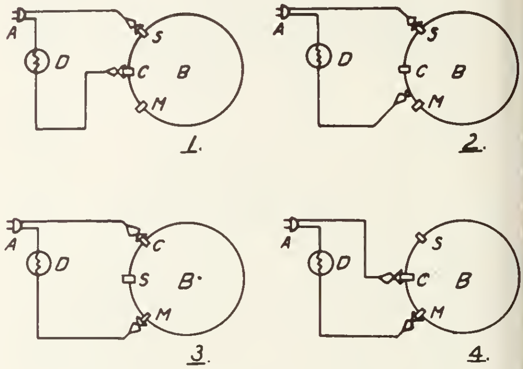
7-48. A table of approximate wattage reading for small hermetic motors.

swings to zero, it means that the unit will not start turning.

Approximate wattage readings for small hermetic motors is shown in Figure 7-48.

7-55. EXTERNAL SERVICING OF THE MOTOR

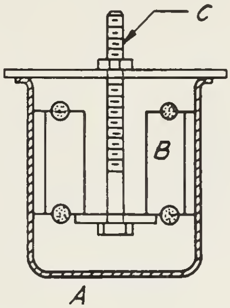
The condition of the refrigeration motor can be readily and easily determined with instruments without the necessity of opening the unit. This is done by disconnecting the wires that are connected to the motor terminals and then testing the motor independent of all its external electrical connections. Figure 7-49. A is the plug, B is the hermetic motor, D is the light bulb 25 (watt), while the starting winding terminal is S, the common terminal is



7-49. Checking a hermetic motor electrically. A. Plug; B. Motor; C. Common terminal; S. Starting terminal; M. Running terminal; 1. Continuity of starting winding; 2. Ground; 3. Continuity of both windings; 4. Continuity of running winding.

C and the running or main winding terminal is M. In part (1) the starting winding is being checked for continuity. If the bulb (D) lights, it means the current is flowing through the starting winding (S to C), and that there is no open spot in the windings. In part (2) the windings are being checked for a ground; that is, to see if any part of any of the internal wiring or the terminals are touching or making electrical contact with the metal parts of the unit. If the bulb (D) lights when one of the electrical leads is touched to any of the terminals, and the other lead or clip is touched to the clean or bare metal body of the dome, it means that electricity is flowing along the internal wires and through a grounded wire into the metal work. Be sure the terminals are clean and dry during this test, or

they may be temporarily grounded by dirt. In part (3) the continuity of both the running and starting windings is being checked. Another trouble that sometimes occurs, especially if the unit has been overheated, is the shorting of the motor winding between themselves without a ground being formed. Any shorting of the motor windings will increase the current draw, decrease the power and overheat the unit. A shorted unit can sometimes be detected by an interruption in the steady hum of the motor when it is running, that is, a noticeable beat occurs in addition to the steady hum. To check



7-50. Removing a press fit stator. A. Dome; B. Stator; C. Puller.

for this short, one can roughly determine its existence by the test light (D). The test light (D) will be brighter than normal if some of the windings are shorted. A better way is to use an ohmmeter and check the resistance of the coils. As models are checked, record the data. Repeated tests have shown that the approximate resistance of domestic unit windings are as follows:

H.P.	Ohmmeter Running Winding	Starting Winding
1/8	4.7	18
1/6	2.7	17
1/5	2.3	14
1/4	1.7	17

7-56. REPAIRING THE HERMETIC MOTOR

The motor may need rewinding, and as the windings are always in the stator, this stator must be removed. The motor stator is usually bolted to the compressor body and dowel pinned to obtain extreme accuracy of alignment. First, disconnect the wires from the terminals and carefully label them and the three terminals. Then mark the parts to assure they will be assembled in correct manner (center punch). Keep the parts in a separate labeled tray. It is good practice to torque the nuts and bolts as they are removed, to learn how much to tighten them on assembly. Improper tightening may warp the body out of its normal tolerance and cause considerable trouble. Some stators are pressed in the dome to increase the cooling action on the stator windings. This type of stator must be power pulled and gear pullers or special pullers are used to carefully remove it, Figure 7-50.

After the stator is removed, it can be rechecked electrically for grounds, opens, and shorts. The trouble may sometimes be repaired quickly without the motor needing to be rewound. If the motor needs rewinding, this operation must be done by an expert motor rewinder. It is necessary to see that the following important things are done:

a. The wire size must be exactly the same.
b. The number of turns must be exactly the same.
c. The insulation must be specially made to be immune to the refrigerant and oil even in the presence of moisture.
d. The work must be done in a dry, clean, and dust-free place.

Many of the refrigeration supply houses have replacement stators for

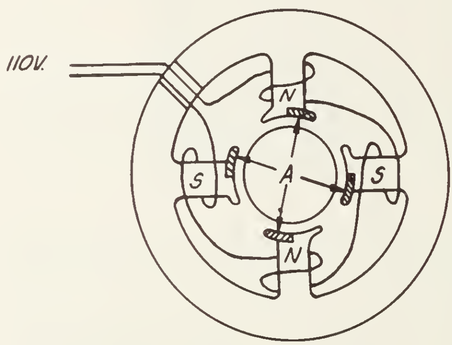
hermetic units. It is important to remember that the workmanship must be of the highest quality. It is costly to do all the dismantling over again; the first repair must be right.

7-57. SERVICING FAN AND FAN MOTOR

Several hermetic units use motor-driven fans to force condenser cooling air through the ducts and over the condenser and condensing units. To obtain efficient air movement the fan and condenser are carefully shrouded or housed in sheet metal. The fans are very carefully balanced and run almost noiselessly. The fans are usually fastened to the motor shaft with Allen set-screws. Some of these motors have sealed bearings (bushings) and require no oiling while others need oiling (SAE 10 or 20) amounting to one drop per bearing each six months. A few motors are on the market that use only one bearing. The motors are usually fastened on brackets and are mounted in rubber, Figure 7-51.

7-51. A replacement fan and motor with universal mounting brackets to fit a variety of condensing unit designs.
(Airserco Mfg. Co., Inc.)

The motors are usually of the shaded pole type. The shaded pole produces a moving magnetic field perpendicular to the field pole and starts the rotor turning, Figure 7-52. Approximately one half of each pole face has a small copper plate insert (A). This insert slows up the build up of the magnetic field through the copper plate enough to cause a rotating motion of the field. This action gives time for an induced built up action of the magnetism in the rotor (opposite magnetism) to be attracted by it. This action continues as the alternating current changes the polarity of the poles and rotor. Although this design has less starting torque than other type motors, it is very successful in small motors 1/6 to 1/100 H.P., Figure 7-53. Generally, the fan motor leads are connected to the common terminal and the running winding terminal of the compressor motor. This connection puts the fan motor in parallel with the compressor motor and allows it to be controlled by the thermostat. The safety overload cut-out is also put in the circuit ahead of the fan so its functioning will also cut out the fan motor.



7-52. A shaded pole fan motor. S. South polarity; N. North polarity; A. Shaded pole (copper).

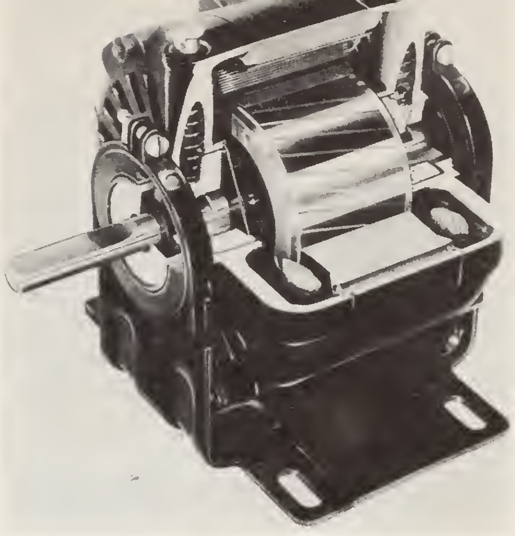
The most common troubles are:

a. Loose connections
b. Dry bearings
c. Worn bearings

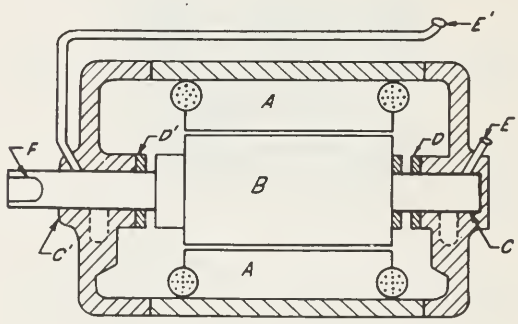
d. Burned-out motor
e. Loose fan
f. Out-of-balance fan
g. Fan blades touching housing

Loose or dirty connections will cause too much voltage drop and the fan motor will lose speed, hum loudly and overheat. A sensitive voltmeter will quickly locate the faulty connection. Do not rely on visual inspection. Dry bearings will cause the same symptoms as in the previous statement, but this condition will last only a short time before the bearings will either seize (bind) or become badly worn. Worn bearings will permit the rotor to vibrate in the stator causing noise. Also the magnetic air gap will vary and cause an annoying hum. When the bearings wear badly enough to permit a rotor to rub on the stator the motor will burn out quickly. Occasionally, the end play (D) of the rotor becomes excessive and causes the motor to produce a distinct knock. Also a reconditioned motor may have the bearing (bushing) inserts off position to the extent of forcing the rotor out of its magnetic center along its shaft. When the motor is running, it should float between the extremes of its end play. One may check this by touching the end of the rotor shaft lightly as the motor is running. It should move back and forth and then settle in between the extremes of the end play. If the rotor cannot assume its magnetic center, it will hum excessively and heat up unduly. Figure 7-54. A is the stator, B is the rotor, CC' are the bearings (bronze bushings), D and D' are the end play portions. When running, the heaviest magnetic flow from the stator tries to line up with the heaviest magnetic flow from the rotor B. This aligning must take place with end play clearance at D and D'. The total clearance is usually about .030 or 1/32 in.

A rattle in the fan motor is sometimes caused by the fan being loose on the motor shaft. This noise can easily be remedied by tightening the setscrew that fastens the fan hub to the shaft. The smaller fans have either a round shaft or a flat spot milled on the shaft (F). If the fan is abused, the blades may be forced out of position and one or more blades will vibrate causing undue noise. The easiest repair is to replace the injured fan. Any attempt to rebalance the blades is very difficult unless special static and dynamic balances are available. When the fan blades touch the fan housing, it may be caused by the motor being out of line or the shroud or housing may be warped. The



7-53. A high starting torque shaded pole motor. (Redmond Co.)



7-54. A rotor running in its magnetic center. A. Stator; B. Rotor; C and C' Bearings; D and D' End play washers; and E'. Oil cups; F. Pulley set screw contact surface.

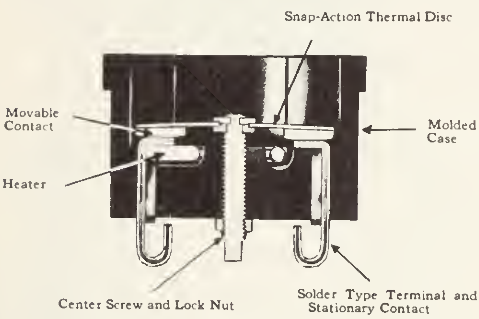
contact spot is usually easily detected and remedied.

7-58. MOTOR PROTECTION

Originally refrigerators had only plug or cartridge fuses to protect them. The fuse had to be large enough to carry the starting current, because the starting current is much larger than the running current, the fuse was then too large. If the running winding of the motor used the full fuse amperage for any length of time, the motor would overheat and be ruined, Figure 7-55.

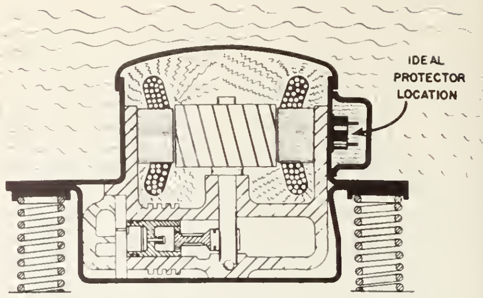
H.P.	110 volt single-phase AC R.I. or capacitator motors	115 volt DC compound wound motors
1/8..	4	3
1/6..	4	3
1/4..	6	4
1/3..	8	6
1/2..	10	8
3/4..	15	10

7-55. Maximum fuse rating for running protection. (American Society of Refrigerating Engineers)



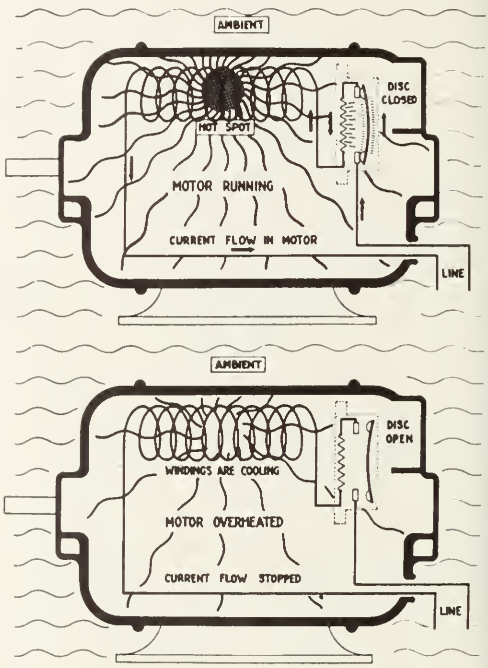
7-56. A bi-metal disc device used to protect the motor. (Spencer Thermostat Div., Metals and Controls Corp.)

To eliminate this inadequacy, time fuses were installed in the circuit. These devices allow an excessive current flow for a very short period of time (such as in starting), but they break the circuit if the current flow is excessive for any length of time.



7-57. A bi-metal overload protector installed to protect against an over heated compressor. (Spencer Thermostat Div., Metals and Controls Corp.)

Two designs were used; one used a gear soldered to a shaft, and a lever under a spring load was attached to this gear. If the motor consumed too much current for too long, the heat from a resistance coil would melt the solder and the gear would release, opening the circuit. Another type used a heating coil and a bi-metal strip. The



7-58. A bi-metal overload protector installed inside an open type electric motor. (Spencer Thermostat Div., Metals and Controls Corp.)

bi-metal would bend enough if the heating coil became warm and would open the circuit.

All these devices, however, would only stop the mechanism if the current load was too high. If due to excessive heating from any source, the motor would overheat and the unit would still run and damage would result. Sources of excessive heat were: high exhaust temperatures, poor air circulation, and friction.

Present refrigerators have safety devices installed that open the electrical circuit if the motor draws too much current, if the motor overheats, and/or if the compressor becomes too hot.

Figure 7-56 illustrates a bi-metal device that opens the circuit if the bi-metal disc reaches a temperature that will cause it to snap in the other direction. Considerable damage can result from overheating either the compressor or the motor. These two conditions could occur without the current draw becoming excessive. It is therefore necessary to use overload devices which will open the circuit if any type of overheating occurs. These controls are temperature operated and receive their heat from the motor, the compressor, and the current draw of the motor.

Figure 7-57 shows a three-way protector on a hermetic system. Figure 7-58 shows the action of a bi-metal snap action current-actuated and heat-actuated overload protector in a conventional motor.

7-59. REVIEW QUESTIONS

1. List the types of motors used in domestic refrigeration.
2. How many field windings are used in 110-220 volt repulsion-start induction motors?
3. Why must an open motor be cleaned regularly?
4. Do all repulsion-start induction motors have brush-lifting mechanisms?
5. What is the purpose of short-circuiting the commutator of a repulsion-start induction motor?
6. Explain the two types of commutators.
7. What is the running winding wattage of a 1/8 H.P. hermetic motor?
8. Why is a plug fuse inadequate protection for a motor?
9. What advantage does a capacitor motor have over a repulsion-start induction motor?
10. How often should motor bearings be oiled?
11. Why do some motors have rubber or spring mountings?
12. What kind of electric motors are usually used in hermetic refrigerators?
13. What are the common voltages used on direct current motors?
14. How can radio interference caused by the refrigerator motor be reduced?
15. How many terminals does a hermetic motor usually have?
16. How many windings does a hermetic motor stator have?
17. Why are some motors called split-phase motors?
18. What is the most common design problem with hermetic motors?
19. Why are hermetic motor field windings insulated in a special way?
20. What kind of rubber does a replacement terminal have?
21. What is a capacitor?
22. Is the capacitor connected in

series with the starting winding?
23. What usually happens in the starter winding circuit when the motor reaches the correct speed?
24. What type motors are used to power fans used on hermetic systems?
25. How is the fan motor electrically connected to compressor motor?
26. Why is the hermetic motor sometimes run backwards?
27. How may a shorted capacitor be detected?
28. What is voltage drop?
29. How much may the voltage drop at the motor terminals before it causes trouble?
30. How should the wiring be marked for easy circuit tracing?
31. What is the magnetic center of a motor?
32. What is electrical continuity?
33. Describe a compound wound D.C. motor.
34. How long does current flow in one direction when 60 cycle current is used?
35. Why is yarn used in some electric motors?

Chapter 8

REFRIGERANTS

To obtain a transfer of heat from the inside of a cabinet to the outside or in order to refrigerate, a heat carrier must be used.

Fluids which can be changed easily from a liquid to a gas and from a gas to a liquid are used as the medium because such a change of state is always accompanied by a change in heat content. Some fluids are better than others. The most popular ones, especially for automatic refrigeration, are discussed in the next few paragraphs.

8-1. REQUIREMENTS FOR REFRIGERANTS

There are certain desirable characteristics which a fluid used as a refrigerant should possess. They are:

1. It should be non-poisonous.
2. It should be non-explosive.
3. It should be non-corrosive.
4. It must be non-flammable.
5. Leaks should be easy to detect.
6. Leaks should be easy to locate.
7. It should operate under low pressure (low boiling-point).
8. It should be a stable gas.
9. It should be easy to lubricate parts moving in its presence.
10. It should be non-toxic.
11. It should have a well balanced latent heat of evaporation value per unit of weight.
12. It should have a small relative displacement to obtain a certain refrigeration effect.
13. Some difference between the vaporizing pressure and the condensing pressure should be a minimum.

Some common refrigerants in use at present are:

1. Sulphur dioxide SO_2 . . .(Par. 8-19)
2. Methyl chloride CH_3CL.(Par. 8-17)
3. Ammonia NH_3. . . . . . .(Par. 8-15)
4. Dichlorodifluoromethane (Freon 12) $C\ Cl_2F_2$ . . . (Par. 8-6)
5. Iso-butane (Freezol) . .(Par. 8-22)
6. Ethyl chloride C_2H_5CL.(Par. 8-16)
7. Carbon dioxide CO_2 . . .(Par. 8-4)
8. Methyl formate $C_2H_4O_2$ (Par. 8-18)
9. Methylene chloride (Carrene) CH_2CL_2 . . . .(Par. 8-13)
10. Chlorotrifluoromethane (Freon 13) $C\ ClF_3$ . . . .(Par. 8-8)
11. Dichlorotetrafluoroethane (F-114) $C_2CL_2F_4$ . . . .(Par. 8-12)
12. Dichloromonofluoromethane F-21 (Thermon) $CH\ CL_2F$ . .(Par. 8-9)
13. Monochlorodifluoromethane F-22 $CHClF_2$ . . . .(Par. 8-10)
14. Freon 11 Carrene No. 2 (Par. 8-5)

The first requirements are almost self-explanatory because it is only natural that an automatic mechanism be safe from the possibility of being poisonous, flammable, or even explosive.

The refrigerant must be non-corrosive in order that the more common metals may be used for constructing the machine and for giving a long life to all the parts.

The refrigerant should be such that its presence and its source may be very easily detected in case of leaks. This is mainly a service feature.

Name	Chemical Symbol	Trade Name	Molecular Weight	Odor	Toxity	Flammability	Pressure psia at 5 F.	Pressure psia at 86 F.	Latent Heat at 5 F.	Sp.Heat of Liquid at 5 F.	Critical Temperature of	Critical Pressure psia	Sp. Volume of Gas at 5 F.	Density of Liquid in a 5 F.#/ cu.ft.	CP/CV	Sp. Heat of Liquid at 86 F.
Sulphur Dioxide	SO_2		64.06	Pungent	High	Non	11.81	66.45	172.3	.34	314.8	1141.5	6.421	92	1.256*	.34
Methyl Chloride	CH_3Cl		50.489	Sweet	Med.	Slight	20.89	95.53	180.6	.45	289.6	969.2	4.530	61	1.20	.4
Ammonia	NH_3		17.031	Pungent	High	Slight	34.27	169.2	565	1.10	271.4	1651	8.150	41.11	1.247	1.10
Iso-Butane	$(CH_3)CH$	Freezol	58.07	Sweet	....	Yes	14.0	65.76	173.5	.5	272.7	522	6.46	37.40	1.11	.75
Ethyl Chloride	C_2H_5Cl	Alcozol	64.51	Etheral	Med.	Yes	4.65	27.10	177	.47	369	764	17.55	59.00	1.13	.42
F-12	CCl_2F_2		120.9	Sweet	Low	Non	26.61	107.9	69.46	.215	232.6	582.0	1.485	90	.....	.243
Carbon Dioxide	CO_2		44.005	Non	Med.	Non	334.4	1039.0	116	.5	87.8	1066.2	.2673	61.22	1.30**	1.95
Methyl Formate	$C_2H_3O_2$		60.04	Slight	....	Slight	1.96	13.69	236	.515	417	870	46.7	.....	....	.515
Methylene Chloride	CH_2Cl_2	Carrene No.1	84.9	Sweet	....	Yes	1.17	10.6	162.1	.34	421	670	50.58	.....	....	.34
F-114	$C_2Cl_2F_4$		170.93	Sweet	Low	Non	6.76	36.2	55#	.15#	294.3	474.0	.....	99.1#	....	.20#
F-21	$CHCl_2F$	Thermon	102.92	Sweet	Low	Non	5.5	30.5	105.5	.26	353.3	750.0	8.83	90.01	....	.26
F-22	$CHClF_2$		86.48	Sweet	Low	Non	43.02	174.5	93.4	11.97	204.8	716	1.246	83.34	....	.34
F-11	CCl_3F	Carrene No.2	137.38	Sweet	Low	Non	29.31	18.28	84.0	.197	388.4	635.0	12.3	97.8	....	.20
F-113	$C_2Cl_3F_3$		187.4	Sweet	Low	Non	.98	7.86	70.62	.199	417.4	495	27.04	103	....	.26
Propane	C_3H_8		44.06	Sweet	Low	Yes	41.9	155	170.2	.56	302	661.5	2.48	34.33	....	.55
Ethane	C_2H_6		30.04	Sweet	Low	Yes	236.0	675.0	150.5	.66	90.1	730	.533	26.96	....	.83
Butane	C_4H_{10}		58.12	Sweet	Low	Yes	8.2	41.6	170.7	.51	308	529	9.98	38.41	....	.51
Kulene 131	CF_3Br			Etheral	Low	Non	77.93	261.8	44.88	.182	1535	587	.3854	112	....	.10

*at 70 F. **at 32 F. #at 70 F.

8-1. A table of properties of common refrigerants.

National Refrigeration Safety Code Group	National Board of Fire Underwriters' Refrigerant Toxicity Classification					
	Class					
	1	2	3	4	5	6
Group 1.						
Carbon dioxide					X	
F-12						X
Kulene-131						X
F-21						
F-114						X
Carrene #1				X		
F-11						
F-22					X	
F-113				X		
Methylene chloride				X		
Group 2.						
Ammonia		X				
Dichloroethylene				X		
Ethyl chloride				X		
Methyl chloride				X		
Methyl formate			X			
Sulphur dioxide	X					
Group 3.						
Butane					X	
Ethane					X	
Iso butane					X	
Propane					X	

8-2. A tabulation of common refrigerants by National Refrigeration Safety Code groups and by National Board of Fire Underwriters toxicity classification.

It is desirable to keep normal pressures in the refrigerator as close to atmospheric pressure as possible, because any excessive differences greatly aid any leaking tendencies, overwork the compressor, and decrease the efficiency of the valves.

In order to stand years of repeatedly changing its state, it is necessary to use a very stable gas or refrigerant in an automatic machine and the refrigerant must not be harmful to the lubricants used. Figure 8-1 is a table of properties of common refrigerants.

8-2. CLASSIFICATION OF REFRIGERANTS

Refrigerants have been classified by two different national groups. They are:

The National Refrigeration Safety Code.

The National Board of Fire Underwriters.

The National Refrigeration Safety Code divides all refrigerants into three groups. These are:

Group I - Safest of the refrigerants: Freon 113, Methylene Chloride, Freon -11, Freon -21, Freon 114, Freon -12, Carrene -7, Freon -22, Kulene 131, Carbon dioxide, Freon -13, Freon -14.

Group II - Toxic and somewhat flammable refrigerants: Dichloroethylene, Methyl Formate, Ethyl chloride, Sulphur dioxide, Methyl chloride, Ammonia.

Group III - Very flammable refriger-

ants:
Butane, Iso-Butane, Propane, Ethane, Ethylene, Methane.

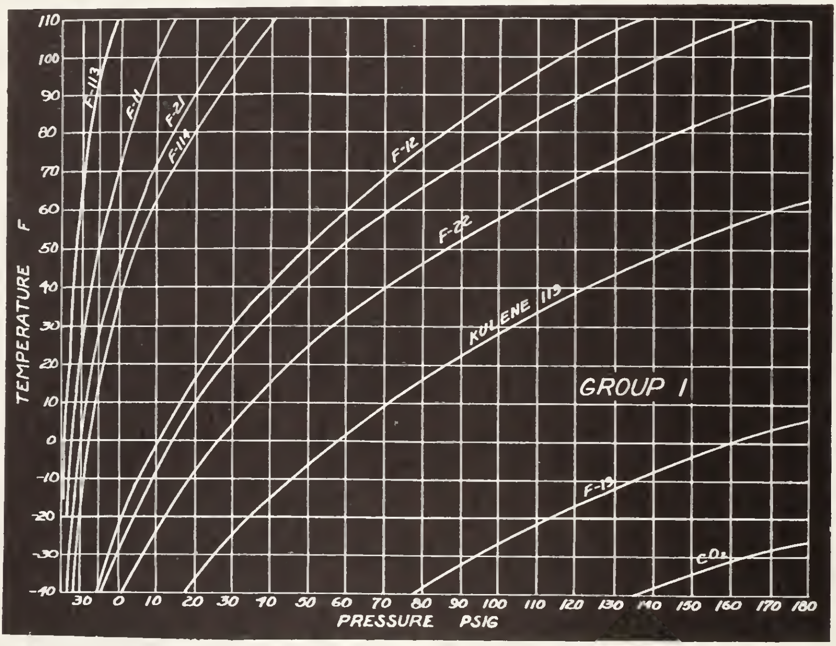
The National Board of Fire Underwriters has also classified refrigerants based mainly on their degree of toxicity. There are six divisions in this scale. Class one is the most toxic, while Class six is the least toxic. Figure 8-2 lists common refrigerants by group and by toxicity.

One should use a refrigerant that has the best rating in both classifications if a choice is possible.

Dichlorotetraflouromethane
D F-114 $C_2Cl_2F_4$
Dichloromethane (Carrene No. 1)
(Methylene Chloride) CH_2Cl_2
Trichloromonofluoromethane
F-11 (Carrene No. 2) CCl_3F
Monochlorodifluoromethane
F-22 $CHClF_2$

The pressure-temperature curves for the Group I refrigerants are shown in Figure 8-3.

The refrigerants in this group may be used in the greatest quantities in any installation. The code allows systems to use up to 20 pounds of this refrigerant in hospital kitchens; up to 50 pounds (indirect system) Chapter 29 in public assemblies; up to 50 pounds in residential use provided special precautions are taken, and up to 20 pounds in residential air conditioning systems.



8-3. Pressure temperature curves for Group One refrigerants.

8-3. GROUP I REFRIGERANTS

The Group I refrigerants are considered the safest refrigerants on the basis of fire hazard and toxicity. The refrigerants in Group I are:

Carbon dioxide CO_2
Dichlorodiflouromethane
F-12 $C\ Cl_2F_2$
Dichloromonoflouromethane
F-21 $C\ H\ Cl_2F$

8-4. CARBON DIOXIDE

Carbon dioxide differs considerably

Carbon Dioxide

Temp. F	Pressure psig	Pressure psia	Volume Gas cu.ft./lb.	Density Liquid lb./cu.ft.	Heat Content B.T.U./lb. Liquid	Heat Content B.T.U./lb. Latent
-40	131.2	145.9	.6113	69.6	0	137.9
-30	163.3	178.0	.5025	68.2	4.7	133.6
-20	200.4	215.0	.4165	66.7	9.2	129.5
-10	242.8	257.5	.3465	65.2	13.9	125.0
0	291.1	305.8	.2905	63.7	18.8	120.1
5	317.6	332.3	.2659	62.8	21.3	117.6
10	345.7	360.4	.2435	61.9	24.0	114.8
20	407.1	421.8	.2048	60.2	29.6	108.9
30	475.9	490.6	.1720	58.2	35.6	102.2
40	552.6	567.3	.1442	56.0	41.8	95.0
50	638.0	652.7	.1204	53.6	48.5	86.6
60	732.7	747.4	.0995	50.75	55.7	76.5
70	837.8	852.5	.0800	47.4	63.7	64.1
80	954.6	969.3	.0600	42.2	74.0	45.0
86	1031.0	1045.7	.0479	37.2	83.4	27.1
87.8	1057.4	1072.1	.0345	29.1	97.1	0

8-4. A table of the properties of carbon dioxide.

in its characteristics from many of the refrigerants. This difference is especially marked in the matter of the pressures encountered within the machine, the operating pressures in the CO_2 machine being many times higher than those encountered in most of the others.

At ordinary temperatures and pressures, CO_2 is a colorless and odorless gas considerably heavier than air. It is non-explosive, non-flammable, and non-toxic. The boiling-point of carbon dioxide is so extremely low that even at 5 F. a pressure of over 300 psi is required to prevent its evaporation, while with a temperature of 80 F. in the condenser, a pressure of almost 1,000 psi is required to liquefy it. Its critical temperature is 87.8 F. so that it can be used only where relatively cold water is available for condenser cooling, and it cannot be used at all with the air-cooled type of condenser. It is not used in local domestic machines, but has been used in Europe.

As a result of the high operating pressures, the compressor of the CO_2 machine is quite small for relatively large refrigerating capacity, and the machine is therefore particularly adapted to use on shipboard where space is at a premium and safety is a prime necessity. The latent heat of evaporation of carbon dioxide at 5 F. is 116 Btu per pound. Leaks may be located by an oil film or soap solution. A large leak will be easily detected from the cloud of condensation or vapor produced at the leak. This refrigerant is used in large installations where leaks will soon be detected by the operator in charge of the system.

As much as 12 pounds of this refrigerant can be used for each 1000 cubic feet of air conditioned space (a room 10 ft. x 12.5 ft. x 8 ft).

Figure 8-4 is a table of the more common properties of carbon dioxide. As mentioned in Chapter 1, carbon dioxide can be formed into dry ice. That is, solidified carbon dioxide can be formed starting at -69.9 F. under a pressure of 60.4 psig. This solid exists at atmospheric pressure at -109.4 F. As it vaporizes at this low pressure it

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	28.42"	.739	44.21	101.1	0.00	87.48
-30	27.81"	1.034	32.33	100.5	1.97	86.70
-20	27.03"	1.42	24.06	99.9	3.94	85.93
-10	26.01"	1.92	18.17	99.03	5.91	85.16
0	24.72"	2.56	13.94	98.3	7.89	84.38
5	23.95"	2.93	12.27	97.8	8.88	84.00
10	23.10	3.352	10.83	97.5	9.88	83.60
20	21.08"	4.34	8.52	96.72	11.87	82.82
30	18.61	5.56	6.78	95.94	13.88	82.03
40	15.61"	7.032	5.447	95.14	15.89	81.22
50	12.00	8.80	4.421	94.34	17.92	80.40
60	7.73"	10.90	3.636	93.53	19.96	79.57
70	2.64"	13.40	2.993	92.71	22.02	78.71
80	1.61	16.31	2.492	91.88	24.09	77.84
86	3.58	18.28	2.242	91.38	25.34	77.31
90	4.99	19.69	2.091	91.04	26.18	76.95
100	8.90	23.60	1.765	90.19	28.27	76.03
110	13.39	28.09	1.499	89.34	30.40	75.08
120	18.50	33.20	1.281	88.47	32.53	74.10
140	30.80	45.50	.9505	86.69	36.84	72.07
150	38.15	52.85	.8240	85.78	39.02	71.00
160	46.34	61.04	.7176	84.85	41.23	69.89

8-5. A table of the properties of Freon 11 (Carrene No. 2).

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	10.92"	9.32	3.911	94.58	0	73.50
-30	3.26	12.02	3.088	93.59	2.03	72.67
-20	.58	15.28	2.474	92.58	4.07	71.80
-10	4.50	19.20	2.003	91.57	6.14	70.91
0	9.17	23.87	1.637	90.52	8.25	69.96
5	11.81	26.51	1.485	90.00	9.32	69.47
10	14.65	29.35	1.351	89.45	10.39	68.97
20	21.05	35.75	1.121	88.37	12.55	67.94
30	28.46	43.16	0.939	87.24	14.76	66.85
40	36.98	51.68	0.792	86.10	17.00	65.71
50	46.69	61.39	0.673	84.94	19.27	64.51
60	57.71	72.41	0.575	83.78	21.57	63.25
70	70.12	84.82	0.493	82.60	23.90	61.92
80	84.06	98.76	0.425	81.38	26.28	60.52
86	93.2	107.9	0.389	80.63	27.72	59.65
90	99.6	114.3	0.368	80.11	28.70	59.04
100	116.9	131.6	0.319	78.80	31.16	57.46
110	136.0	150.7	0.277	77.46	33.65	55.78
120	157.1	171.8	0.240	76.02	36.16	53.99
130	180.2	194.9	0.208	74.46	38.69	52.07
140	205.5	220.2	0.180	72.73	41.24	50.00

8-6. A table of the properties of Freon F-12.

changes from a solid to a gas and does not go through its liquid state.

8-5. FREON 11 (CARRENE #2)

Trichloromonofluoromethane (CCl_3F) is a synthetic chemical produced especially for refrigeration use. It is a stable refrigerant, it is non-flammable and non-toxic. As much as 35 pounds of this refrigerant can be used for each 1000 cubic feet of air conditioned space (a room approximately 10 ft. x 12.5 ft. x 8 ft). This refrigerant is considered a low pressure refrigerant as it has a standard low side pressure at 5 F. of 24 inch vacuum and a high side pressure at 86 F. of 18.2 psi, Figure 8-5. Its latent heat at 5 F. is 84.0 Btu, but each pound forms 12.3 cubic feet of gas at this temperature. This refrigerant is extensively used in large centrifugal compressor systems. Leaks may be detected by using the electronic detector or by using the halide torch. It is safe to use 35 pounds of this refrigerant per 1000 cubic feet of air conditioned space.

8-6. FREON 12 (DICHLORODIFLUOROMETHANE)

Freon or dichlorodifluoromethane is a colorless, almost odorless gas with a boiling-point of -21.7 F. at atmospheric pressure. It is non-toxic, non-corrosive, non-irritating, and non-flammable. It is generally prepared by replacing chlorine in carbon tetrachloride with fluorine. Chemically it is inert at ordinary temperatures and thermally stable up to 1022 F., Figure 8-6.

Freon has a relatively low latent heat value and this is a decided advantage in the smaller refrigerating machines, because the large quantity of liquid circulated will permit the use of less sensitive, more accurate, and more positive operating and regulating mechanisms.

It operates at a low but positive head and back pressure, and with a good volumetric efficiency.

A Freon leak may be detected by means of a halide lamp. This lamp may be described as a torch burning alcohol, which under normal conditions produces a colorless flame. A tube fastened to the base of the burner is used to conduct the air suspected of containing the vapor through the flame and over metallic copper. Owing to the breaking down of the refrigerant in the flame a volatile copper halide is formed, and a flame color changes from the normal colorless to bright green if the air contains as much as 0.01 per cent of the gas.

It is only slightly soluble in water, and the solution formed is very slightly corrosive to any of the common metals used in refrigerator construction. The addition of mineral oil to the gas has no effect upon the corrosive action, except possibly to decrease the amount of discoloration caused by the free water.

1. It is non-flammable.
2. It is non-explosive.
3. It is non-irritating.
4. It is non-toxic.
5. It has no odor even in fairly high concentrations.
6. It is stable.
7. It is non-corrosive.
8. It has no effect on flowers, fruits, vegetables, dairy products, furs, or other materials being refrigerated.

From an engineering viewpoint, complicated heat tables are used to study the properties of the refrigerants, but all that is needed to be known in order to understand the operation and to be able to service the mechanism is the temperature-pressure curve of the fluid, i.e., the vaporization temperature at any pressure, Figure 8-7.

It is safe to use 30 pounds of this refrigerant per each 1000 cubic feet of air conditioned space.

This refrigerant is available in a variety of amounts in special cylinders and it can also be obtained in hermetically sealed one pound cans. The cylinder code color is white.

A typical F-12 cycle is shown in Figure 8-8. The cycle is for a frozen foods unit.

8-7. KULENE

This refrigerant was especially developed for low temperature systems. It has a boiling temperature of -73.6 F. at atmospheric pressure. Its condensing pressure at 86 F. is 247.1 psig. It has a gas volume of .3854 cubic feet per pound at 5 F. and a latent heat of 44.88 Btu per pound at 5 F.

This refrigerant is non-toxic and non-flammable which would put it in the Group I, Class 5 or 6, Fig. 8-9. It is a patented refrigerant and it has not been used extensively to date. It is usable with all common metals.

8-8. FREON 13 (CHLOROTRIFLUOROMETHANE)

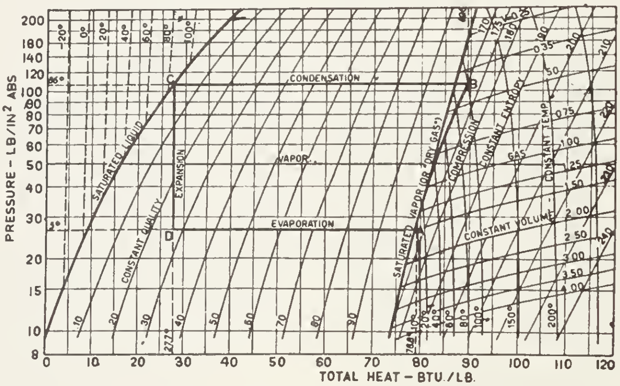
Freon -13 is a refrigerant especially developed for low temperature applications. It is a safe refrigerant to use both on a flammability basis and a toxic basis.

Its boiling pressure at 5 F. is 17? psig and it must be condensed at temperatures less than 83.93, its critical temperature. Its latent heat at 5 F. is 45.56 Btu per pound, Figure 8-10.

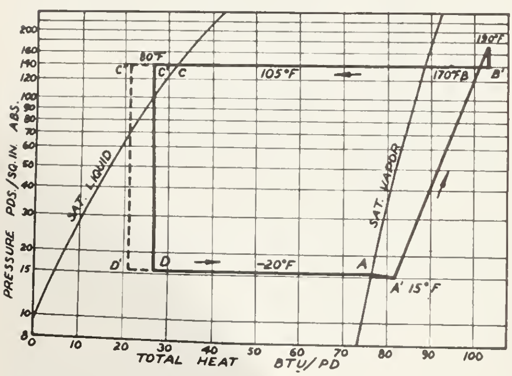
The development of this refrigerant indicates the steady increase in low temperature refrigeration applications, Figure 8-11.

8-9. FREON 21 (DICHLOROMONOFLUOROMETHANE)

The 1935 Crosley rotary units used a refrigerant called Thermon. It is a



8-7. A pressure-heat chart for F-12.
(American Society of Refrigerating Engineers)



8-8. A pressure-heat diagram of freezer application for F-12 refrigerant.

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	17.71	32.41	.8811	119.3	0	50.25
-30	25.24	39.94	.7246	117.9	1.72	49.14
-20	34.15	48.85	.5977	116.0	3.47	47.98
-10	44.59	59.29	.4988	114.5	5.24	46.78
0	56.44	71.14	.4202	112.9	7.04	45.52
5	63.23	77.93	.3854	112.0	7.95	44.88
10	70.14	84.84	.3546	111.2	8.86	44.21
20	85.6	100.3	.3003	109.5	10.71	42.84
30	103.3	118.3	.2556	107.8	12.58	41.39
40	123.1	137.3	.2169	105.9	14.48	39.87
50	145.7	160.4	.1856	103.9	16.40	38.26
60	170.2	184.9	.1587	101.8	18.35	36.55
70	197.7	212.4	.1366	99.5	20.32	34.71
80	227.4	242.1	.1173	96.9	22.32	32.73
86	247.1	261.8	.1068	95.2	23.52	31.47
90	260.3	275.0	.1000	94.0	23.34	30.58
100	297.0	311.7	.0842	90.8	26.39	28.21
110	337.0	352	.0699	86.8	28.46	25.56
120	381	396	.0562	82.0	30.56	22.51
130	429	444	.0423	75.5	32.68	18.86
140	481	496	.0302	66.5	34.83	14.11
150	527	552	.0221	52.0	37.00	5.88
160						

8-9. A table of the properties of Kulene 131.

refrigerant very similar to F-114, having many of its characteristics, and its operating pressures are almost the same. Its boiling temperature under atmospheric pressure is 48 F., Figure 8-12. It is practically non-explosive and non-flammable. Its odor is similar to chloroform and it is not irritating in any way. It mixes in practically all proportions with oil and may be tested for leaks by using a halide torch. It is a non-corrosive and non-poisonous refrigerant. It operates at 18.8 inches of vacuum at 5F. and at 15.8 psi at 86 F. Its liquid has a density at 5 F. of .0111 cubic feet per pound and at 86 F. of 0.119 cubic feet per pound. Its saturated vapor has a density at 5 F. of 8.83 cubic feet per pound and at 86 F. of 1.87 cubic feet per pound. The specific heat of the liquid is approximately .26 Btu per pound per F. The latent heat of the refrigerant at 5 F. is 105.5 Btu per pound.

Approximately 13 pounds of this refrigerant can be safely used per 1000 cubic feet of air conditioned space.

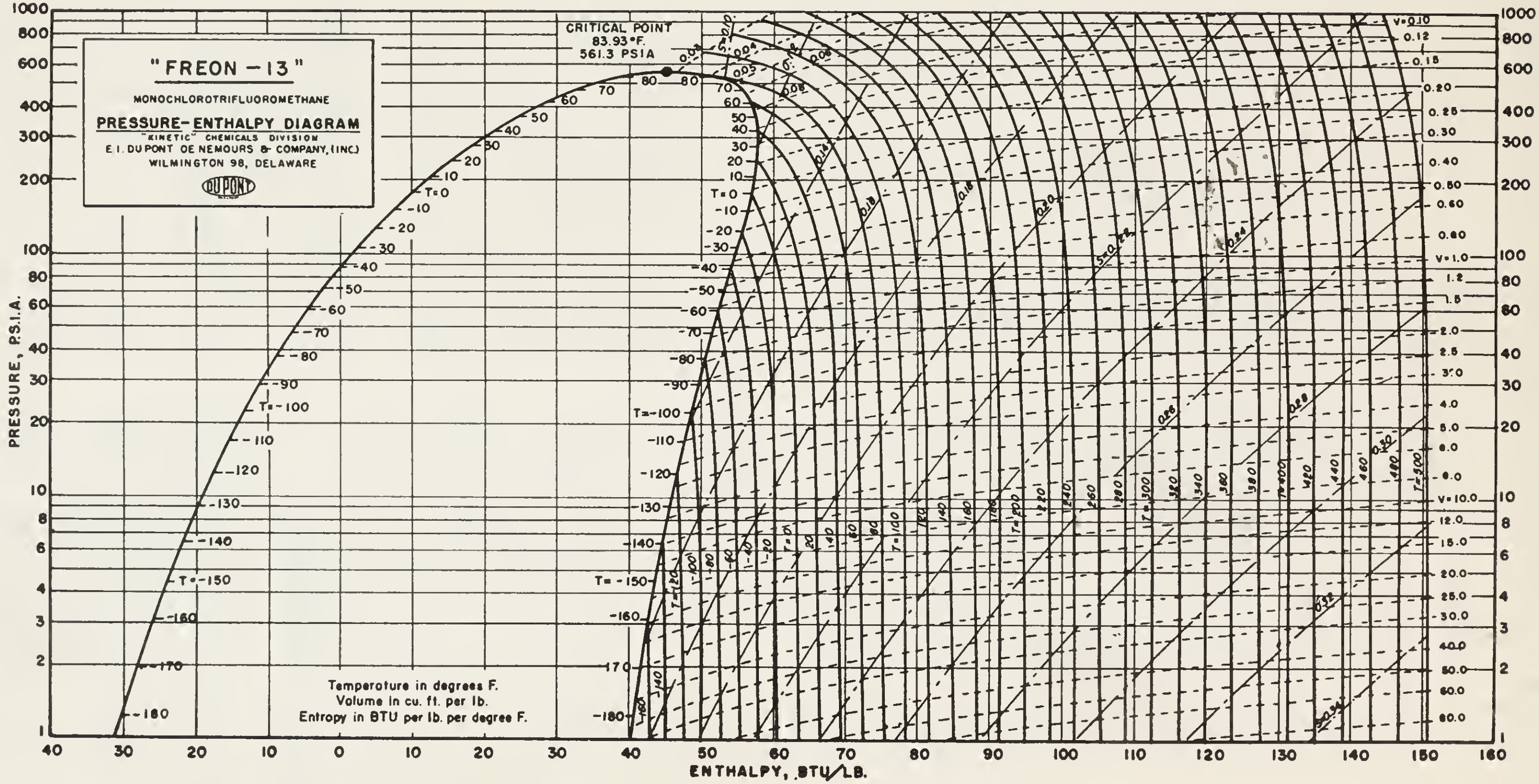
8-10. FREON 22 (MONOCHLORODIFLUOROMETHANE)

The Freon 22 refrigerant is a synthetic chemical specially developed for those refrigeration installations that have a very low temperature cooling unit. One example of this application is in fast freezing units which maintain a temperature of -20 F. to -40 F. The operating pressures of this refrigerant are such that it is not necessary to operate at below atmospheric pressures in order to obtain these low temperatures.

The boiling point is -41 F. at atmospheric pressure. It has a latent heat of 93.6 Btu per pound at 5 F. The normal head pressure at 86 F. is 160 psi, Figure 8-13. This refrigerant is very stable and is non-toxic, non-

Temp.F	Pressure		Volume cu.ft./lb.	Density lb./cu.ft.	Heat Content B.T.U./lb.	
t	psig	psia	Vapor	Liquid	Liquid hf	Latent h
-200	*29.04"	0.4329	61.33	105.6	-34.551	73.096
-190	*28.40"	0.7490	36.74	104.4	-32.429	72.029
-180	*27.40"	1.238	22.99	103.2	-30.298	70.970
-170	*25.92"	1.967	14.942	102.0	-28.208	69.904
-160	*23.60"	3.104	9.750	100.8	-26.083	68.808
-150	*20.83"	4.464	6.976	99.60	-24.010	67.783
-140	*16.78"	6.455	4.950	98.33	-21.902	66.696
-130	*11.43"	9.080	3.605	96.99	-19.792	65.596
-120	* 4.51"	12.48	2.681	95.69	-17.671	64.473
-110	2.11	16.81	2.031	94.34	-15.527	63.316
-100	7.53	22.23	1.5642	93.02	-13.387	62.138
-90	14.19	28.89	1.2232	91.66	-11.241	60.941
-80	22.28	36.98	0.9689	90.17	-9.052	59.672
-70	31.98	46.68	0.7766	88.73	-6.843	58.362
-60	43.49	58.19	0.6289	87.26	-4.604	56.993
-50	57.01	71.71	0.5139	85.69	-2.320	55.546
-40	72.73	87.43	0.4234	84.10	0.000	54.023
-30	90.90	105.6	0.3512	82.44	2.363	52.416
-20	111.7	126.4	0.2930	80.71	4.809	50.668
-10	135.4	150.1	0.2454	78.86	7.484	48.630
0	162.1	176.8	0.2066	76.98	10.052	46.638
10	192.1	206.8	0.17443	74.91	12.696	44.479
20	225.7	240.4	0.14732	72.73	15.443	42.100
30	263.2	277.9	0.12437	70.32	18.247	39.472
40	304.9	319.6	0.10455	67.70	21.370	36.450
45	327.5	342.2	0.09565	66.27	22.979	34.769
50	351.2	365.9	0.08734	64.68	24.651	32.958
55	376.1	390.8	0.07945	62.97	26.418	30.946
60	402.3	417.0	0.07189	61.09	28.310	28.677
65	429.8	444.5	0.06468	58.96	30.322	26.137
70	458.7	473.4	0.05767	56.46	32.515	23.193
75	489.0	503.7	0.05027	53.36	35.110	19.382
80	520.8	535.5	0.04131	48.85	38.527	13.565
83.93	546.6	561.3	0.02772	36.08	45.271	....

8-10. A table of the properties of F-13.
("Kinetic" Chemicals Div.)



8-11. Pressure-heat diagram for F-13.
("Kinetic" Chemicals Div.)

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	27.16"	1.358	32.09	94.52	0	114.56
-30	26.08"	1.888	23.61	93.79	2.36	113.40
-20	24.67"	2.578	17.66	93.04	4.71	112.25
-10	22.87"	3.463	13.43	92.28	7.07	111.10
0	20.59"	4.582	10.35	91.52	9.44	109.93
5	19.25"	5.243	9.13	91.13	10.63	109.34
10	17.75"	5.978	8.09	90.74	11.81	108.76
20	14.25"	7.699	6.39	89.96	14.21	107.57
30	9.98"	9.793	5.11	89.16	16.61	106.37
40	4.84"	12.32	4.13	88.35	19.04	105.15
50	0.63	15.33	3.37	87.54	21.49	103.90
60	4.20	18.90	2.77	86.71	23.98	102.62
70	8.38	23.08	2.30	85.87	26.49	101.30
80	13.26	27.96	1.92	85.03	29.03	99.95
86	16.53	31.23	1.73	84.52	30.56	99.12
90	18.88	33.58	1.62	84.17	31.59	98.55
100	25.34	40.04	1.37	83.31	34.18	97.11
110	32.70	47.40	1.17	82.43	36.79	95.63
120	41.05	55.75	1.00	81.54	39.46	94.07
130	50.45	65.15	.86	80.65	42.13	92.48
140	61.02	75.72	.76	79.74	44.86	90.80
150	72.81	87.51	.65	78.82	47.62	89.06
160	85.91	100.6	.56	77.90	50.43	87.26

8-12. A table of the properties of F-21.
("Kinetic" Chemicals Div.)

corrosive, non-irritating, and non-flammable.

Water is more soluble in F-22 than F-12 by a ratio of 40:1. Water must be kept at a minimum in these refrigerants so dryers or dessicants are used to remove most of the moisture. Because of F-22's affinity for water more dessicant is needed to dry it. Some of the properties of Freon 22 are shown in Figure 8-14.

8-11. FREON 113 (TRICHLORO-TRIFLUOROETHANE)

Freon 113 is a very low pressure refrigerant that is used with centrifugal compressors in air conditioning systems of large tonnage capacity. At 5 F. it evaporates at 27.92 inches vacuum, the gas occupies 27.04 cubic feet per pound and the latent heat is 70.62 Btu per pound. At 86 F., the refrigerant condenses at a 13.93 inch vacuum, Figure 8-15. It can be tested for leaks by warming the refrigerant to 200 F. which will produce a pressure of 39.96 psig. A halide torch is used. At room temperature and pressure, the refrigerant is a liquid and it can therefore be carried in sealed tins rather than in cylinders. It is classed as a Group I refrigerant as to fire safety, and as a Class 4 refrigerant as to toxicity.

8-12. FREON 114 (DICHLORO-TETRAFLUOROETHANE)

The 1934-54 Frigidaire refrigerator mechanism used a refrigerant called F-114. This machine is a hermetic rotary machine using a capillary refrigerant control. The refrigerant has a boiling-point at atmospheric pressure of 38 F. The refrigerant has properties very similar to that of F-12 in regard to water and oil combination. The refrigerant is of the same family as F-12,

Temp. F	Pressure psig	psia	Gas Volume cu.ft./lb. Sat.Gas	Density Liquid lb./cu.ft.	Heat Content B.T.U./lb. Liquid	Latent
-155	29.51"Hg	.19901	188.1	97.67	-29.07	115.85
-145	29.23"	.3375	114.5	96.99	-26.52	114.46
-135	28.80"	.5511	72.33	96.27	-23.99	113.10
-125	28.15"	.8692	47.23	95.53	-21.47	111.76
-115	27.21"	1.329	31.77	94.76	-18.98	110.45
-105	29.90"	1.976	21.96	93.97	-16.48	109.15
-95	24.09"	2.865	15.54	93.14	-13.98	107.85
-85	21.67"	4.055	11.26	92.29	-11.47	106.55
-80	20.18"	4.787	9.65	91.85	-10.22	105.90
-70	16.55"	6.57	7.192	90.95	- 7.69	104.57
-60	11.89"	8.86	5.452	90.03	- 5.16	103.24
-50	6.03"	11.74	4.192	89.08	- 2.58	101.86
-40	.610	15.31	3.279	88.10	0.00	100.46
-30	5.02	19.72	2.590	87.09	2.62	99.01
-20	10.31	25.01	2.074	86.06	5.28	97.51
-10	16.59	31.29	1.681	84.99	7.96	95.96
0	24.09	38.79	1.373	83.90	10.63	94.39
5	28.33	43.02	1.246	83.34	11.97	93.59
10	32.93	47.63	1.130	82.78	13.28	92.79
20	43.28	57.98	.9369	81.63	15.98	91.15
30	55.23	69.93	.7816	80.45	18.74	89.39
40	69.02	83.72	.6559	79.25	21.70	87.39
50	84.70	99.40	.5537	78.02	24.73	85.25
60	102.5	117.2	.4695	76.75	27.83	82.95
70	122.5	137.2	.4000	75.46	30.99	80.50
80	145.0	159.7	.3417	74.15	34.27	77.86
86	159.8	174.5	.3113	73.36	36.28	76.19
90	170.1	184.8	.2928	72.81	37.61	75.06
100	197.9	212.6	.2517	71.35	40.98	72.08
110	228.7	243.4	.2167	69.78	44.35	68.94
120	262.6	277.3	.1871	68.10	47.85	65.67

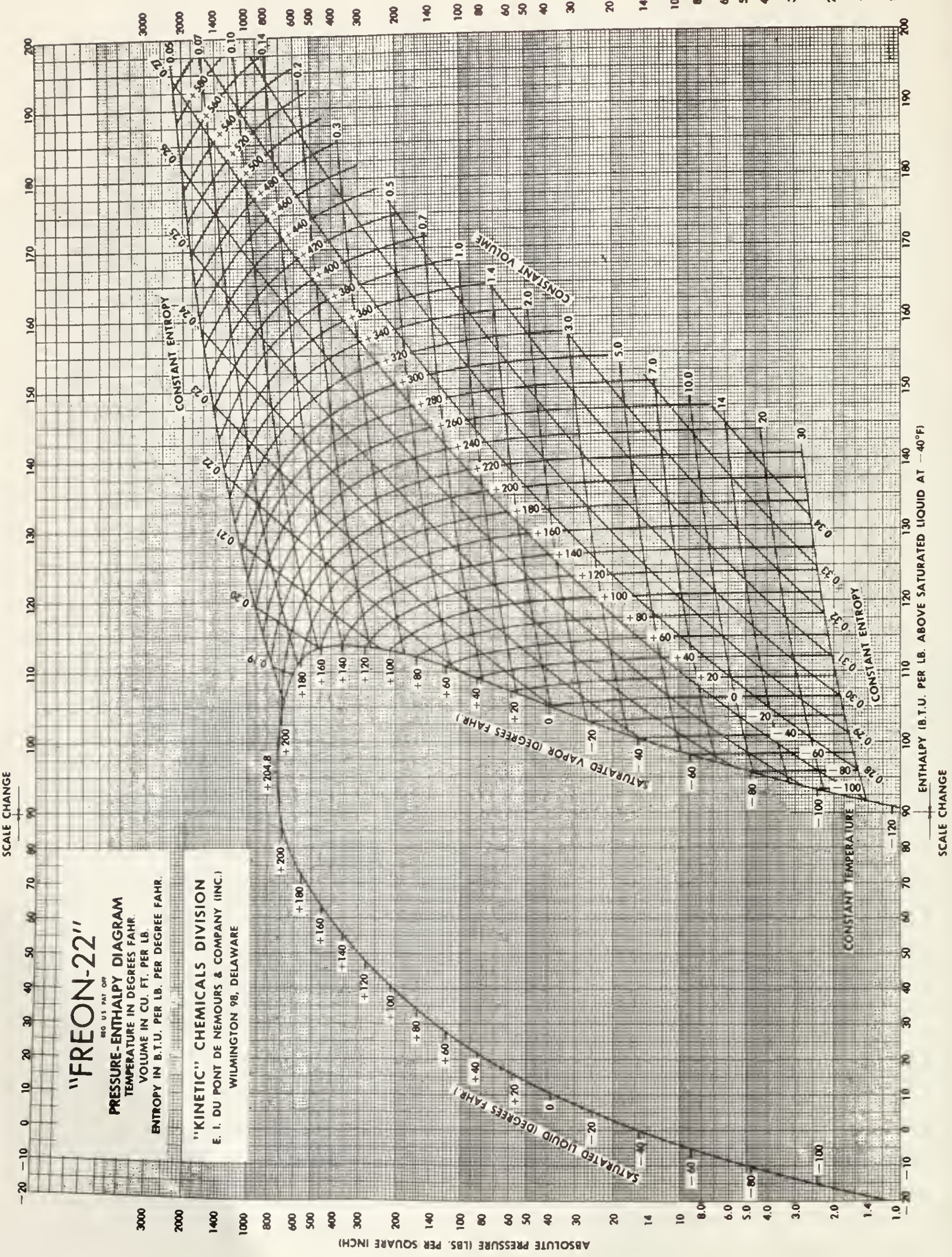
8-13. A table of the properties of F-22.
("Kinetic" Chemicals Div.)

but its operating pressures are considerably lower. At 86 F. it has a pressure of 21.5 psi gauge while at 5 F. its pressure is 16.1 inches of mercury vacuum, Figure 8-16. It is a colorless liquid having a slight odor. In addition to being non-explosive it is a non-corrosive liquid which will not corrode even in the presence of water. The halide torch is used to test it for leaks. Its boiling-point at atmospheric pressure is 38.4 F., while at 20 F., it has a latent heat of vaporization of 55 Btu per pound. The specific volume of this liquid and the specific heat of the vapor at 70 F. are .0109 cubic feet per pound, and .15 Btu per pound respectively. The volume of the vapor when saturated at 70 F. is 1.15 cubic feet per pound, and the specific gravity of the liquid at this temperature is 1.47.

Approximately 40 pounds of this refrigerant can be used for each 1000 cubic feet of air conditioned space.

8-13. METHYLENE CHLORIDE (CARRENE #1)

This refrigerant (dichloromethane), more popularly known as Carrene No. 1, is a very low pressure refrigerant



8-14. A pressure-heat chart for Freon —22. ("Kinetic" Chemicals Div.)

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40					0	
-30	29.31"	.2987	82.26	105.7	1.97	72.68
-20	29.05"	.4288	58.61	104.8	3.96	72.09
-10	28.69"	.6046	42.48	104.2	5.96	71.51
0	28.21"	.8377	31.31	103.5	7.98	70.91
5	27.92"	.9802	27.04	103.1	8.98	70.62
10	27.60"	1.142	23.45	102.8	10.00	70.32
20	26.80"	1.534	17.81	102.1	12.03	69.72
30	25.79"	2.031	13.71	101.3	14.08	69.12
40	24.52"	2.655	10.68	100.5	16.16	68.49
50	22.94"	3.427	8.426	99.7	18.24	67.87
60	21.02"	4.374	6.713	99.0	20.35	67.57
70	18.68"	5.523	5.404	98.2	22.48	66.56
80	15.87"	6.902	4.392	97.5	24.63	65.88
86	13.93"	7.856	3.893	97.0	25.93	65.46
90	12.53"	8.545	3.600	96.6	26.80	65.18
100	8.59"	10.48	2.976	95.7	28.99	64.46
120	0.70	15.40	2.078	94.0	33.48	62.93
140	7.23	21.93	1.491	92.2	38.05	60.31
160	15.74	30.44	1.094	90.4	42.74	59.55
180	26.52	41.22	.819	88.7	47.53	57.66
200	39.96	54.66	.624	86.8	52.45	55.62

8-15. A table of the properties of F-113.
("Kinetic" Chemicals Div.)

	Pressure		Volume Gas	Density	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	26.12"	1.866	14.02	102.25	0	65.91
-30	24.72"	2.557	10.45	101.37	2.27	65.03
-20	22.91"	3.444	7.921	100.47	4.54	64.16
-10	20.63"	4.564	6.095	99.56	6.81	63.29
0	17.79"	5.958	4.756	98.62	9.09	62.41
5	16.14"	6.772	4.221	98.15	10.23	61.98
10	14.31"	7.671	3.758	97.68	11.37	61.54
20	10.07"	9.753	3.005	96.71	13.66	60.66
30	4.99"	12.25	2.429	95.73	15.97	59.16
40	0.52	15.22	1.982	94.73	18.28	58.86
50	4.03	18.73	1.632	93.71	20.61	57.94
60	8.13	22.83	1.354	92.68	22.95	57.00
70	12.87	27.57	1.133	91.63	25.30	56.05
80	18.34	33.04	0.9541	90.56	27.68	55.05
86	21.99	36.69	.8632	89.91	29.11	54.45
90	24.59	39.29	.8084	89.47	30.06	54.05
100	31.69	46.39	.6890	88.37	32.47	53.01
110	39.71	54.41	.5901	87.25	34.89	51.94
120	48.74	63.44	.5077	86.08	37.33	50.83
130	58.84	73.54	.4387	84.89	39.80	49.67
140	70.09	84.79	.3803	83.66	42.29	48.47

8-16. A table of the properties of F-114.
("Kinetic" Chemicals Div.)

having operating pressures of 27.5 inches vacuum at 5 F. and an 8.8-inch vacuum at 86 F. Its chemical formula is CH_2Cl_2 and its freezing temperature is -142 F. Figure 8-17. The gas has a slight odor which is not distasteful. It may be carried or stored in tins, although the refrigerant evaporates under room conditions fast enough to warrant sealing the cans in which it is stored. The refrigerant may be poured into a system through a funnel when charging. The specific heat of the liquid is .34 and its boiling-point at atmospheric pressure is 105 F. Its critical temperature is 421 F. and it has a latent heat of 162.1 Btu per pound at 5 F. Carrene has been used by the Carrier Corporation in air conditioning equipment, and was used in the Grunow domestic refrigerator. In combination with water the corrosive action is negligible, but any moisture may freeze at the refrigerant control.

The Grunow used a 5/8 inch O.D. suction line because this refrigerant forms 49.9 cubic feet of gas per pound at 5 F. However, this does not increase the power required to run the machine as the high side pressure is below atmospheric pressure.

8-14. GROUP II REFRIGERANTS

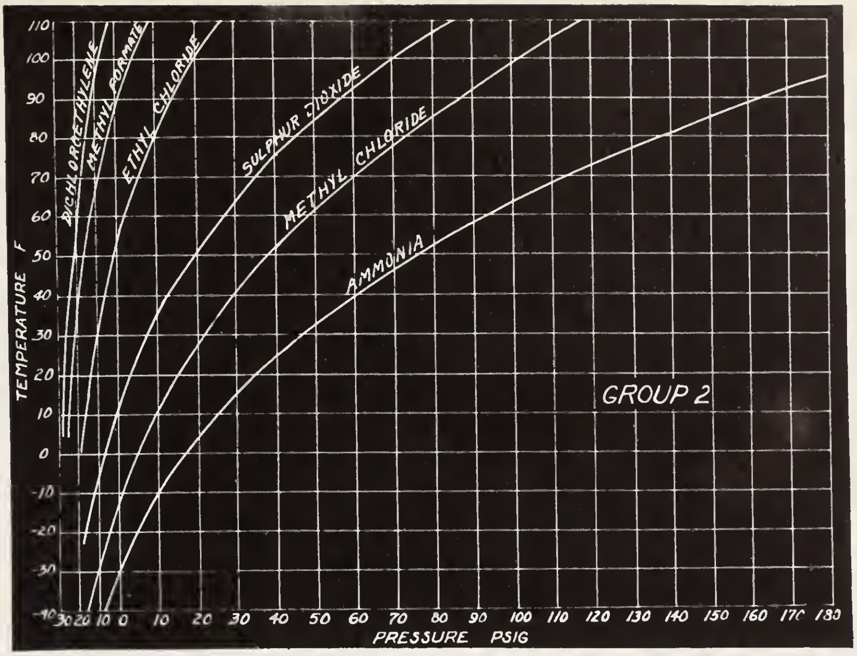
The Group II refrigerants are toxic refrigerants that are irritating to breathe and may or may not be slightly flammable.

	Pressure		Volume Gas	Heat Content B.T.U./lb.	
Temp.F.	psig	psia	cu.ft./lb.	Liquid	Latent
-40					
-30					
-20					
-10					
0					
5					
10	27.12"	1.38	42.55	3.4	161.0
20	26.01"	1.92	31.40	6.8	158.8
30	24.71"	2.56	23.90	10.2	156.7
40	23.04"	3.38	18.60	13.6	154.4
50					
60	18.72"	5.52	11.68	20.4	149.7
80	12.02"	8.81	7.50	27.2	144.8
86					
90					
100	2.97"	13.25	5.14	34.0	139.7
110					
120	4.50	19.20	3.65	40.8	134.2
130					
140	12.09	26.79	2.69	47.6	128.4

8-17. A table of the properties of methylene chloride (Carrene No. 1). (American Society of Refrigerating Engineers)

The refrigerants in Group II are:

Ammonia	NH_3
Dichloroethylene	$C_2H_2Cl_2$
Ethyl Chloride	C_2H_5Cl
Methyl Chloride	CH_3Cl
Methyl Formate	$HCOOCH_3$



8-18. Pressure temperature curves for Group Two refrigerants.

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	8.7"	10.41	24.86	43.1	0.0	597.6
-30	1.6"	13.90	18.97	42.65	10.7	590.7
-20	3.6	18.30	14.68	42.2	21.4	583.6
-10	9.0	23.74	11.50	41.8	32.1	576.4
-0	15.7	30.42	9.116	41.3	42.9	568.9
5	19.6	34.27	8.150	41.15	48.3	565.0
10	23.8	38.51	7.304	40.85	53.8	561.1
20	33.5	48.21	5.910	40.4	64.7	553.1
30	45.0	59.74	4.825	39.9	75.7	544.8
40	58.6	73.32	3.971	39.45	86.8	536.2
50	74.5	89.19	3.294	38.96	97.9	527.3
60	92.9	107.6	2.751	38.5	109.2	518.1
70	114.1	128.8	2.312	38.0	120.5	508.6
80	138.3	153.0	1.955	37.45	132.0	498.7
86	154.5	169.2	1.772	37.16	138.9	492.6
90	165.9	180.6	1.661	36.9	143.5	488.5
100	197.2	211.9	1.419	36.35	155.2	477.8
110	232.3	247.0	1.217	35.85	167.0	466.7
120	271.7	286.4	1.047	35.25	179.0	455.0
125	293.1	307.8	.973	.....	185.1	488.9

8-19. A table of the properties of Ammonia.

Sulphur dioxide SO_2

The pressure-temperature curves for Group II refrigerants are shown in Fig. 8-18.

Ammonia was one of the first refrigerants used. However, it is now used in large industrial installations only with the exception of the Servel absorption refrigerator. The use of sulphur dioxide has practically disappeared although at one time it was almost the only refrigerant used in domestic

refrigerators. Methyl chloride has also almost disappeared in new machines. However, there are many sulphur dioxide and methyl chloride charged units still in use.

8-15. AMMONIA

Ammonia is one of the most common of all the refrigerants for large industrial use. It is a chemical compound of nitrogen and hydrogen (NH_3) and under ordinary conditions is a colorless gas. Its boiling temperature at atmospheric pressure is -28 F. and its melting-point from the solid -108 F. The low boiling-point makes it possible to secure refrigeration at temperatures considerably below zero without resorting to pressures below atmospheric in the evaporator. Its latent heat at 5 F. is 565 Btu per pound, so that large refrigerating effects are possible with the use of relatively small-sized machinery. Condensers for ammonia machines are almost always of the water-cooled type. Under ordinary operating conditions, the condenser pressure will vary from 150 to 200 pounds per square inch, Figure 8-19.

Ammonia is somewhat flammable and with the proper mixture of air will form an explosive mixture. Accidents from this source, however, are rare. Ammonia gas is not classed as poisonous, but its effect on the respiratory system is so violent that only very small quantities of it can be breathed. About .35 volumes per 100 volumes of air is the strongest concentration bearable for any length of time. Because of its pronounced and distinguishable odor and also the white smoke-like fumes that it forms in the presence of sulphur vapor, ammonia leaks may be quickly and easily detected.

Ammonia, although attacking copper and bronze in the presence of a little moisture, does not corrode iron or steel, and it presents no special problems in connection with lubrication other than those attendant upon the extreme temperatures encountered in the system. Ammonia gas is extremely soluble in water. It is used in large machines and in practically all of the absorption types. Refer to Figure 8-18 for the vapor pressure curves for this refrigerant.

8-16. ETHYL CHLORIDE

Ethyl chloride is a little used refrigerant which is similar in many respects to methyl chloride, being a member of the same chemical family. The outstanding difference is found in the low pressure at which it evaporates. At atmospheric pressure, the boiling temperature of ethyl chloride is 55.6 F. Therefore, it is necessary to operate with an evaporator pressure below that of the atmosphere. This disadvantage is somewhat counterbalanced by the correspondingly low pressure encountered in the condenser. Pressures in the condenser of from 10 to 20 psi are common, and, as a result of the low pressure operations, ethyl chloride is sometimes more suited for use in the rotary compressor than in the more common reciprocating type.

The use of ethyl chloride presents the same difficulty of lubrication and leak detection as does methyl chloride, and the substance itself possesses similar explosive and combustible characteristics. Its odor is similar to that of ether and its effect is of a like nature but much milder. Its latent heat of evaporation at 5 F. is 177 Btu per pound. It is not being used in any refrigerator produced at present, although it was used in the Holmes two-stage rotary machine and in the Welsbach. Refer to Figure 8-18 for the vapor pressure curves for this refrigerant.

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	15.9"	7.0	12.6	63.98	0	183.5
-30	11.9"	9.0	9.82	63.40	4	182
-20	6.9"	11.5	8.09	62.77	7.2	181.8
-10	.05"	15.0	6.46	62.17	11.0	180.5
- 0	3.8	18.5	5.18	61.51	14.5	179.5
5	6.19	20.89	4.65	61.20	16.3	179.0
10	8.6	23.3	4.18	60.89	18.0	178.5
20	13.6	28.3	3.41	60.23	21.7	177.3
30	20.3	35.0	2.81	59.62	25.2	176.0
40	28.1	42.8	2.31	58.96	28.9	174.8
50	36.3	51.0	1.93	58.15	32.5	172.8
60	46.3	61.0	1.61	57.62	36.5	170.5
70	57.8	72.5	1.34	56.91	40.5	167.5
80	72.3	87.0	1.14	56.22	44.5	164.5
86	80.83	95.53	1.06	55.77	46.5	163.0
90	87.3	102.0	0.98	55.53	48.0	162.0
100	102.3	117.0	0.85	54.84	52.0	158.5
110	118.3	133.0	0.765	54.12	55.5	155.2
120	139.3	154.0	0.700	53.936	59.0	152
130	161.3	176.0	.580	......	62.5	148.8
140	185.3	200.0	.514	......	67.0	144
150	213.3	228.0	.453	......	71.0	139.6
160	243.3	258.0	.388	......	75.5	134.5

8-20. A table of the properties of Methyl Chloride.

8-17. METHYL CHLORIDE

Methyl chloride is classed as non-corrosive in a dry state. It is a poisonous refrigerant and should be treated with great respect. Carbon tetrachloride, a common solvent in refrigeration work, is closely related and carries the same hazard. Breathing of sufficient quantities of these chlorinate materials will result in suspension of the respiratory functions, damage to the liver, kidneys, and central nervous system. Their effects are cumulative, building one exposure on top of another. Many deaths have resulted from these materials.

The boiling point of methyl chloride at atmospheric pressure is -11.36°F. and its melting point is -136 7°F. Its critical temperature is 289.6°F. The latent heat of evaporation at 5°F. is 178.5 BTU per pound. Condenser pressures are in the vicinity of 100 psi for the methyl chloride machine. The condensing pressure will be substantially reduced when water cooled condensers are used.

Methyl chloride is combustible and explosive but wide usage in the field has established that these properties are not limiting factors if the refrigerant is used with normal caution. Refer to Figure 8-20 for a table of the properties of methyl chloride.

Leaks may be detected in methyl chloride either by the soap bubble method or the halide torch test. In the latter test if methyl chloride is passed through a colorless flame over hot metallic copper, the flame will turn a brilliant blue-green in the presence of minute quantities of the refrigerant.

Much copper plating has been experienced in methyl chloride machines.

We now know that insufficient quantities of desiccant were used and many methyl chloride machines were very wet and acidic. Copper plating was the natural result of these conditions. A drier eight times as large as for the same poundage of "Freon-12" should be used. Copper plating does not take place in dry machines.

Conventional "Freon" oils may be used with methyl chloride. Low wax content oils of this type are preferable to prevent plugging of capillary tubes and expansion valves with wax.

2 inches of vacuum. The gas is slightly flammable and at 5 F. 1 pound forms 47 cubic feet of gas. Its freezing-point is -148 F. and it has a critical temperature of 418 F. The latent heat of the gas at 5 F. is approximately 236 Btu per pound. The specific gravity of the liquid is .9531 and the specific heat of the liquid is .515 Btu per pound.

The General Electric unit, which uses this refrigerant, has a vertically mounted motor under a dome driving a rotary compressor directly. The unit looks similar to this Company's sulphur

	Pressure		Volume Gas	Density Liquid	Heat Content B.T.U./lb.	
Temp.F	psig	psia	cu.ft./lb.	lb./cu.ft.	Liquid	Latent
-40	23.54"	3.136	22.42	95.79	0.00	178.61
-30	21.10"	4.331	16.56	94.94	2.93	176.97
-20	17.93"	5.883	12.42	94.10	5.98	175.09
-10	13.91"	7.863	9.44	93.27	9.16	172.97
0	8.85"	10.35	7.28	92.45	12.44	170.63
5	5.87"	11.81	6.421	92.00	14.11	169.38
10	2.59"	13.42	5.682	91.58	15.80	168.07
20	2.48	17.18	4.487	90.71	19.20	165.32
30	7.00	21.70	3.581	89.76	22.64	162.38
40	12.40	27.10	2.887	88.81	26.12	159.25
50	18.75	33.45	2.348	87.87	29.61	155.95
60	26.23	40.93	1.926	86.95	33.10	152.49
70	34.92	49.62	1.590	86.02	36.58	148.88
80	44.98	59.68	1.321	85.03	40.05	145.12
86	51.75	66.45	1.185	84.44	42.12	142.80
90	56.55	71.25	1.104	84.05	43.50	141.22
100	69.82	84.52	.9262	83.07	46.90	137.20
110	85.06	99.76	.7804	82.03	50.26	133.05
120	106.23	120.93	.6598	80.90	53.58	128.78
130	121.78	136.48	.5595	79.81	56.85	124.39
140	143.91	158.61	.4758	78.61	60.04	119.90

8-21. A table of the properties of Sulphur Dioxide.

8-18. METHYL FORMATE

The General Electric Corporation has produced some refrigerators using methyl formate. This is a relatively rare refrigerant. The chemical formula is HCO_2CH_3 or $C_2H_4O_2$ and its operating pressure at 5 F. is 25.9 inches vacuum while at 86 F. its pressure is

dioxide monitor top refrigerator. Refer to Figure 8-18 for the vapor pressure curves for this refrigerant.

8-19. SULPHUR DIOXIDE

Sulphur dioxide was used in many of

the early automatic refrigeration units. Sulphur dioxide was first produced in 1775 and in addition to its use as a refrigerant, it has considerable use in the industries for such purposes as refining sugar, bleaching wool, preserving food, and fumigating. It is usually produced by the burning of sulphur in the presence of oxygen. Its chemical formula is SO_2. At atmospheric pressure and all temperatures above 14 F. it is a colorless gas of very pronounced odor. Its boiling-point at atmospheric pressure is 14 F. and melting-point -103.4 F. Its critical temperature is about 314.8 F. As a result of its boiling temperature being at 14 F., it is necessary to operate at pressures somewhat below atmospheric when temperatures below this figure are required. Little difficulty, however, has been experienced as a result of this and other advantages tend to offset it. The boiling-point, for instance, makes condensation of the gas easy and it is rarely necessary to exceed a pressure of 100 psi in the condenser. Water-cooled machines with as low as 30 pounds pressure in the high side are not uncommon in winter operation. Refer to Figure 8-21 for a table of the properties of sulphur dioxide.

The latent heat of sulphur dioxide at 5 F. is 169.38 Btu per pound. This is not quite one-third of the value for ammonia under the same conditions; and although it makes necessary a circulation of almost three times the amount of sulphur dioxide as of ammonia for the same amount of refrigeration, it is not a disadvantage in the case of the small capacity machine, for it permits the construction of the parts of a sufficiently large size to be practical and efficient.

Sulphur dioxide is non-explosive and non-flammable. Although of an irritating odor, it is comparatively non-toxic. As little as three parts by volume, in one million parts of air, is enough to produce a noticeable odor and thus call attention to the presence of the gas. In addition to its odor, SO_2 leaks are easily detected and located by means of a 28 per cent solution of ammonia. With this method the most minute leak can be detected. The aqueous ammonia is purchasable in any drug store and when used with a swab the presence of SO_2 is revealed by a white smoke forming when the ammonia vapors and the SO_2 vapors react.

The lubricating problem in connection with SO_2 is perhaps easier than with any other refrigerant, for sulphur dioxide itself possesses certain lubricating properties. It does not react chemically with the proper kind of oil and is approximately 50 per cent heavier than the oil. One must remember that oil is not soluble in any refrigerant while that refrigerant is in its gaseous state. Most oils are somewhat soluble in SO_2 (8 to 10 per cent), but the usual extent of solubility is more of an aid than otherwise, for it permits of a desirable circulation of the lubricant with the refrigerant. The best oil to use is thoroughly dehydrated, pure mineral oil.

The only characteristic of sulphur dioxide that is not desirable from the standpoint of its use as a refrigerant is its action in the presence of moisture. SO_2 combines with water to form sulphurous acid, which attacks the ferrous metals of the system. There is no danger of this, however, when moisture is not present, and modern methods of manufacture have entirely overcome the corrosion hazard. "Baking" or heating all the parts before assembling them into the system minimizes corrosion. Refer to Figure 8-18 for the

vapor pressure curves for this refrigerant.

8-20. GROUP III REFRIGERANTS

Those refrigerants that have a high tendency to burn or form a combustible mixture with a wide range of concentration in air are classified as Group III refrigerants. Under proper design and installation conditions some of these refrigerants perform remarkably well.

The refrigerants in Group III are:

Butane	C_4H_{10}
Ethane	C_2H_6
Iso-Butane	(CH_3) CH
Propane	C_3H_3

The pressure-temperature curves for the Group III refrigerants are shown in Figure 8-22.

8-21. BUTANE

Butane has a pressure-temperature relationship of 13.2 in hg at 5 F. and 30.5 psi at 86 F. It has a latent heat of 170.7 Btu at 5 F. and of 154.0 Btu at 86 F. It forms 9.98 cubic feet of gas at 0 F. and 2.24 cubic feet at 86 F.

8-22. ISOBUTANE

Iso-Butane, or Freezol, is a refrigerant of the butane family of compounds which was used by the Copeland Company in their refrigerators until 1933. Its properties are such that it boils at 10.3 F. at atmospheric pressure and has a freezing-point of -229 F. A good feature of the gas is its critical temperature of 273 F. which is above the temperature of any refrigerator apparatus. The refrigerant is non-corrosive in the presence of water and the lubrication of the system is not difficult. Its chemical formula is the same as that of butane C_4H_{10} but the bonds are different, giving completely different physical characteristics. The gas has a specific volume of 7.17 cubic feet per pound at 0 F. and a latent heat of 159.5 Btu per pound at 5 F.

The only method of testing the system for leaks is to build up a positive pressure and use oil or soap bubbles. A seal leak may be detected by submerging the compressor in a quantity of water after a pressure is built up in the crankcase with air or other means. Another method is to run the compressor with both the suction and discharge service valves closed and with gauges in the gauge openings. An increase in the high side gauge reading indicates a low side leak. A trace of sulphur dioxide may be put into the system for testing for leaks, but the idea is not recommended because if the system is not moisture free, corrosion will follow. Moisture in the normal system will freeze at the expansion valve and clog the orifice, but a dehydrator will remove this trouble. Refer to Figure 8-22 for the vapor pressure curves for this refrigerant.

8-23. PROPANE

Propane is a medium high pressure refrigerant. One must reduce the cooling unit temperature to -14 F. to use pressure below atmosphere.

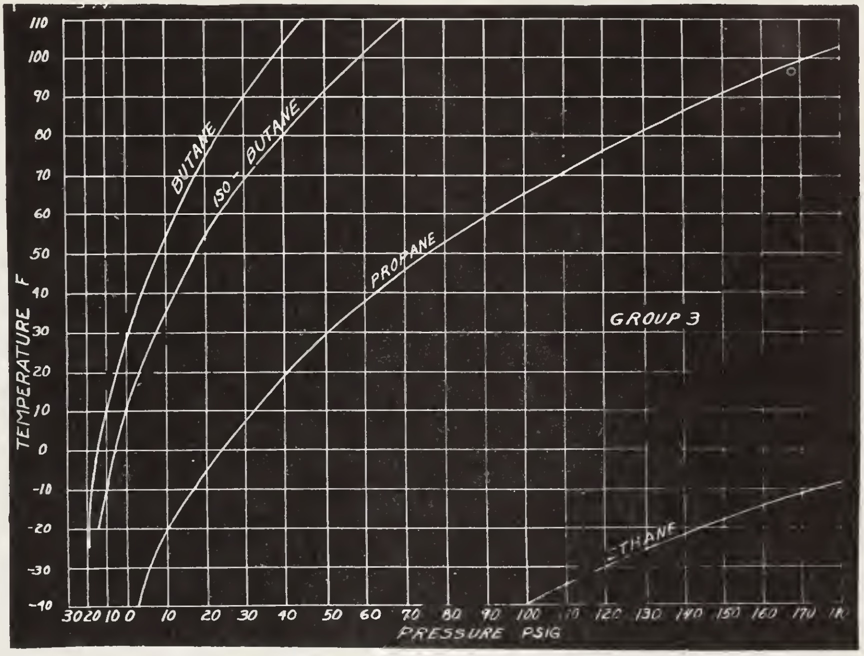
At 5 F. in the evaporator each pound forms 248 cubic feet of vapor at 27.2 psi. At this temperature each pound has a latent heat of 170.2 Btu per pound.

Propane is a common fuel for many heating and power applications. It is a product of refining crude oil. Some cross country refrigerated trucks use propane as a fuel in place of gasoline. Since the propane is confined under pressure in the fuel tank, if it is

allowed to vaporize at a reduced pressure, the heat absorbed in changing from a liquid to a gas amounts to approximately 170 Btu per pound. By using vaporizing coils in the refrigerated truck space this cooling effect is used to aid in maintaining necessary refrigeration within the cargo space.

1. A non-condensible gas in the condenser; air for example. The air won't condense and due to Dalton's Law the head pressure will be the refrigerant's gas pressure plus the air pressure.

2. An overcharge of refrigerant in a system using a low side float, an



8-22 Pressure temperature curves for Group Three refrigerants.

Refer to Figure 8-22 for the vapor pressure curves for this refrigerant.

8-24. HEAD PRESSURES

The proper head pressure, high side pressure, or condensing pressure is very important. If the condensing pressure is too high, the compressor has to work too hard and too much gas is left in the compressor clearance pocket which will reduce the volumetric efficiency and finally the temperature of the exhaust gas will be excessive and may cause oil deterioration. Above normal head pressures are caused by one of four things:

expansion valve, or a thermostatic expansion valve will fill some of the heat removing space in the condenser with liquid refrigerant and reduce the condensers heat removal ability.

3. If either side of the heat transfer surface is dirty, this dirt will act as an insulator and the heat removal capacity of the condenser will be lowered and the condenser temperature must raise to overcome this handicap.

4. If the air movement or the water movement in the condenser is reduced by blocked air passages or poor water line there will not be enough heat removing media to remove the heat from the condenser.

In air cooled condensers, the head pressure should correspond to a temperature between 30 F. and 35 F. higher than the ambient temperature or the temperature of the air passing over the condenser.

In a water cooled condenser, the head pressure should correspond to temperature 15 F. to 20 F. above the exhaust temperature of the water.

8-25. LOW SIDE PRESSURES

The low side pressure in a refrigerating system depends on the use the refrigerating system is put to and the type of evaporating or cooling coil used.

One must first ascertain the temperature that is desired in the cabinet or fixture and then adjust the motor control until this temperature is maintained. However, there are many cases where both a certain cooling coil temperature and a cabinet temperature relationship should exist.

Certain cabinet temperatures are fairly standard and the following is a widely accepted list of cabinet temperatures:

Fixture	Temperature F.
Back Bar	40-45
Beverage Cooler	40-45
Beverage Pre-Cooler	35-40
Candy Case (Display)	65-70
Candy Case (Storage)	58-65
Dairy Display Case	40-45
Double Display Case (Duty)	35-42
Delicatessen Case	40-48
Dough Retarding Refrigerator	35-40
Florist Display Refrigerator	40-50
Florist Storage Case	38-45
Frozen Food Cabinet (Closed)	-5 -0
Frozen Food Cabinet (Open)	-10 -5
Grocery Refrigerator	35-42
Retail Market Cooler	35-42
Pastry Display Case	45-50
Restaurant Service Refrigerator	36-40
Restaurant Storage Cooling	38-45
Top Display Case (Closed)	35-42
Vegetable Display Refrigerator (Open)	35-55
Vegetable Display Refrigerator (Closed)	35-48

Refrigerator temperatures depend on the material put in the fixture. The following list is based on the application of the fixture:

Application	Temperature F.
Candy Storage	29-40
Meats	35-40
Bananas	60-70
Candy Display Storage	60-70
Fresh Meats	28-32
Aging Room	35-38
Chill Room	35-39
Curing Room	38
Freezer Room	-15
Poultry	28-30
Vegetables, Fresh	32-40
Ice Cream Hardening	-25
Ice Cream Storage	-10 -0
Plants and Flowers	38-50
Fur Storage	15-40
Locker Room	0- 5

It is necessary to have the correct sized cooling coil to produce the temperature desired. If the coil is over capacity it will have an above normal temperature and if the coil is undersized it will have to be at a below normal temperature.

The refrigerant will always be colder than the coil when the unit is running and for the same reason the cooling coil will always have a lower temperature than the fixture temperature.

Normally the refrigerant will be 10 F. colder than the coil temperature when the unit is running and the refrigerant and the cooling coil will become the same temperature during the off cycle.

The cooling coil surface temperature is definitely dependent on its size as compared to the heat it must remove from the fixture per unit of time.

A standard air cooling coil of the frosting type (domestic type) will vary from 0 F. to 25 F. and the refrigerant temperature will be about 10 F. lower than this or in the range of -10 F. to 15 F.

8-26. USE OF THE PRESSURE TEMPERATURE CURVES

The vapor pressure curves represent the various pressures produced by the refrigerants under various temperatures. The vertical scale is the F. temperature scale. To determine the pressure of the refrigerant at any particular temperature, read horizontally from the temperature reading until the curve of the particular refrigerant is reached; then move directly down and the pressure may be read on the horizontal scale. For example, the pressure of methyl chloride at a refrigerant temperature of 100 F. is 104 psig. The temperature is always the temperature of the refrigerant. The same curve may be used for determining both the condensing and evaporating temperatures and pressures. The condensing values are the higher values. When using this chart, several things must be kept in mind:

1. The temperature of the refrigerant in the cooling coil is approximately 8 F. to 12 F. colder than the coil when the compressor is running.
2. The temperature of the refrigerant in the cooling coil is the same as the coil temperature when the compressor is stopped.
3. The temperature of the refrigerant in an air-cooled condenser is approximately 30 F. to 35 F. warmer than the room temperature.
4. The temperature of the refrigerant in a water-cooled condenser is approximately 20 F. warmer than the water temperature at the drain outlet.
5. The temperature of the refrigerant in the condenser is the same as the temperature of the cooling medium after the unit has been shut off for 15 to 30 minutes.

8-27. USE OF PRESSURE TEMPERATURE TABLES

The pressure-temperature relationship of the refrigerants under saturated conditions can be shown in the tables as well as pictured in graphs.

The table can also be used to show the volume of one pound of the gas at that temperature, as well as the latent heat, the specific heat of the liquid, and the density of the liquid. All these values are of great value to an engineer and to a sales engineer.

To use the tables select the temperature being investigated in the left hand vertical column and then move across to the other columns horizontally to determine the pressure, etc.

8-28. SELECTION OF REFRIGERANT

To have an economical refrigerator mechanism the designer must choose the refrigerant that will qualify and also be good in the following respects: In order to refrigerate, the gas when passing from a liquid to a gas must absorb heat; that gas which absorbs the most heat per pound as it changes its state is usually the most desirable. That is, any fluid which will answer the practical requirements and which requires a great deal of heat to change it from a liquid to a gas is the refrigerant wanted. There are several other design requirements to be met,

one of which is that the specific volume of the gas, and volume per unit of weight, must be kept small in order that a compressor of small size may be used.

It must not be forgotten that cost and availability determine to a considerable extent the kind of fluid used.

All of the above factors decide which refrigerant is to be used; the final choice is that one which satisfies the greatest number of all of the above and all of the necessary requirements.

8-29. HERMETIC SYSTEM REFRIGERANTS

The first hermetic units produced in the 1920's used sulphur dioxide refrigerants. The properties of this refrigerant are explained in Paragraph 8-19. In the late 1920's and early 1930's methyl chloride was used to some extent. The Grunow refrigerator used Carrene (methylene chloride). In 1934 the Frigidaire Corporation introduced their hermetic unit using Freon 114. This refrigerator has been the exclusive user of this refrigerant in most of their small hermetic units ever since. The Crosley Corporation used F-21 (Thermon) with their 1935 units. However, the most popular hermetic refrigerant has been, and still is, Freon 12 except for low temperature units (Frozen Foods units) where Freon 22 is quite popular. The properties of Freon 12 are described in Paragraph 8-6. The refrigerants used in hermetic refrigeration units must be of the best quality. They must contain an absolute minimum of foreign matter and moisture. And it is imperative to transfer these refrigerants in chemically clean cylinders and lines. Always charge a unit with refrigerant in the gas form (never put liquid in the unit). Always warm the charging cylinder with water, never use an open flame because of danger of overheating.

8-30. CHANGING REFRIGERANTS

It is not recommended to change refrigerants in a machine that has been designed for a particular refrigerant. However, if this has to be done in extreme cases, the following pointers may prevent considerable trouble. In general, it is best to use expansion valves and a dry system when substituting refrigerants rather than attempt to recalibrate float controls; also it should be remembered that many small engineering features that are incorporated in a unit to promote efficiency for the particular refrigerant selected will be lost if a change in refrigerant is made.

If a capillary tube is used it will need replacement if the density or the pressure differences are changed. Always remember to clean the mechanism thoroughly and replace the oil before the refrigerant is changed.

8-31. REPLACING FREON-12 WITH METHYL CHLORIDE

Methyl chloride is the most frequently used substitute for Freon. Its use is only recommended in extreme cases of emergency and Freon (F-12) should be put back into the unit as soon as possible.

Do not put methyl chloride in Freon units that use aluminum gaskets. The conversion may be done in small domestic units without any changes, if automatic expansion valves or high side floats are used. If thermostatic expansion valves are used, they must be readjusted or replaced. The unit will run more of the time; however, the power consumption will not be much greater due to the lower head pressures. The cost of operation may be slightly increased.

Larger units may necessitate a larger motor pulley (25 per cent increase in diameter) in order that the

compressor may be speeded up to take care of the increased volume of gas. This increase in pulley size may demand a longer belt. Excessive compressor speeds should be avoided.

8-32. SUBSTITUTING METHYL CHLORIDE FOR SULPHUR DIOXIDE

It is possible to make this change, but a smaller pulley should be put on the motor, for the compressor will not have to run as fast for methyl chloride; also the higher head pressure under which methyl chloride operates makes it necessary to use a smaller pulley on the motor or to replace the motor with a larger one. If any kind of float refrigerant control is used, it must be replaced with the float for methyl chloride; the density of the two refrigerants is entirely different, as may be seen from the table (Figure 8-20). It is common practice to use an expansion valve to replace float refrigerant controls when changing refrigerants.

8-33. SUBSTITUTING SULPHUR DIOXIDE FOR METHYL CHLORIDE

This may be done, but the compressor must be speeded up and the system must be thoroughly dried out (baked at 200 F. under a vacuum for 8 to 24 hours). The speeding up of the compressor is necessary to handle the increased gas volume. Because of the lower high side pressure, this can usually be done by increasing the size of the motor pulley and without changing the motor. Again, attention must be given to the refrigerant control, if it is other than an expansion valve, to make sure that all floats are calibrated for the refrigerant being used.

8-34. SUBSTITUTING SULPHUR DIOXIDE FOR ISO-BUTANE

It will usually be safe to make such a change without making any change in the pulley sizes, although the motor will have to work a little harder unless a smaller pulley is used. Again, this system must be thoroughly dehydrated by being baked at 200 F. under a vacuum for 8 to 24 hours. Also, the refrigerant controls must be checked to make sure they are calibrated for the new refrigerant.

8-35. SUBSTITUTING SULPHUR DIOXIDE FOR ETHYL CHLORIDE

It is not recommended that this change ever be made, as many radical changes are necessary. However, if it is done, a larger motor must be installed and the system thoroughly dehydrated as for other sulphur dioxide installations. Also, the refrigerant controls must be changed.

8-36. AMOUNT OF REFRIGERANT IN SYSTEM

The amount of refrigerant that should be in a system varies with the type of system. Low side float, automatic expansion valve, and thermostatic expansion valve systems are not critical as to the amount of refrigerant. The method of checking is to charge gas refrigerant into the low side of the system until the cooling coil has its normal amount, the liquid line is at room temperature and there is no hissing sound at the refrigerant control valve. If a pound or two more are put in the unit this extra refrigerant will become a reserve stored in the liquid receiver. The smaller the unit the less amount of refrigerant is needed as a reserve. A sure way to determine if the

system has sufficient refrigerant is to put a sight glass in the liquid line. The appearance of gas bubbles in this sight glass is the sign that the system is short of refrigerant and it should be charged until the gas bubbles disappear, Figure 8-21.

Most systems which use a high side float or a capillary tube are very critical as to their refrigerant charge. If the system is overcharged, the cooling coil will flood and liquid refrigerant will flow down the suction line causing sweating and/or frosting of this line. If the system is undercharged, the cooling coil will be undercharged or starved. The use of accumulator spaces at the outlet of these cooling coils relieves the problem somewhat but one must always be careful of the amount charged into these systems. A very common method of charging these units is to slowly charge these systems until the suction line starts to sweat and/or frost back and then purge a little at a time until the frost back disappears.

Remember that one should always charge a system into the low side if possible and the refrigerant should be put into the system in the gas form. Forcing liquid refrigerant into a system may cause serious damage to the pump and occasionally has caused serious accidents to servicemen.

Also one should remember that if a system is short of refrigerant, that the system has a leak. This leak should be located and corrected before the system is charged.

8-37. REVIEW QUESTIONS

1. Why is ammonia not popular in the compression type, domestic machines?
2. How may one test for sulphur dioxide leaks?
3. Why has ethyl chloride been discontinued as a domestic refrigerant?
4. What is a common head pressure for air-cooled sulphur dioxide refrigerators?
5. What is the method used to locate methyl chloride leaks?
6. What are the low side pressures at 5 F. for sulphur dioxide and methyl chloride?
7. What does "halide" mean?
8. What does toxic mean?
9. What refrigerator used Carrene?
10. What oil properties are required with sulphur dioxide?
11. What other name is F-12 known by?
12. What properties must oil used with methyl chloride have?
13. What is the pressure of Freon-12 at 95 F.?
14. What is the temperature of methyl chloride under a pressure of 20 pounds per square inch gauge?
15. What is the pressure of carbon dioxide at 0 F.?
16. Is it advisable to substitute refrigerants in a system?
17. How may one determine the refrigerant temperature in an air-cooled condenser?
18. What refrigerator used Thermon as a refrigerant?
19. Name the refrigerants that may be tested for leaks with the halide torch?
20. What will be high side pressure (gauge) in an air-cooled condenser using methyl formate while the condensing unit is running if the room temperature is 75 F.?
21. What is the normal head pressure for an air-cooled F-22 system?
22. Is the refrigerant temperature in the cooling coil the same temperature as the cooling coil?
23. What effect does air in the system have on the head pressure?

Chapter 9

DOMESTIC REFRIGERATOR CABINETS

The refrigerator cabinet has undergone considerable change during the forty years of its evolution as a kitchen necessity. The original cabinets were replicas of the ice box. Wood cabinets of multiple door construction and finished in natural wood finishes were common practice. Solid brass, nickel plated hardware was standard. The cabinet lining was galvanized iron or sheet zinc. Wood or wire mesh shelves were used. These units weighed as much as 1000 pounds.

Originally the electric refrigerator consisted of a cooling coil installed in the ex-ice compartment. The condensing unit was ordinarily installed in the basement.

The present day refrigerator is a tremendous improvement over such a unit. Refrigerators to-day are scientific marvels of maximum storage space for minimum exterior dimensions. They have air conditioned interiors; efficient, light weight, long lived refrigeration units; provide temperatures as low as - 20 F.; have finger-tip door control; ice cube removal; shelf availability and functional beauty. These features are all results of considerable research.

Most of the manufacturers have taken advantage of the greater compactness of the hermetic unit to decrease the condensing unit space, and to enlarge the refrigerated space. Some companies have designed units so compact that they are mounted in the back of the cabinet and the full height of the refrigerator can be used for cold storage. Most refrigerator models are examples of this practice or accomplish the same purpose by locating the condensing unit near the bottom and back of the cabinet.

The hardware has been considerably improved for ease of operation and for durability. The practice of concealing the hinges and the latch is still progressing. The cabinets are much lighter as the companies improve on structural design, more efficient insulation, and use lighter mechanisms.

Several concerns have produced refrigerators with overall heights of 30 inches so they may be used as tables Fig. 9-1. Some refrigerators are being incorporated in stove-refrigerator combinations. Automatic defrosting is popular, as is the use of ultra-violet ray lamps. Most cabinets now use a white lacquer exterior and a porcelain interior with a variety of colored plastic trim.

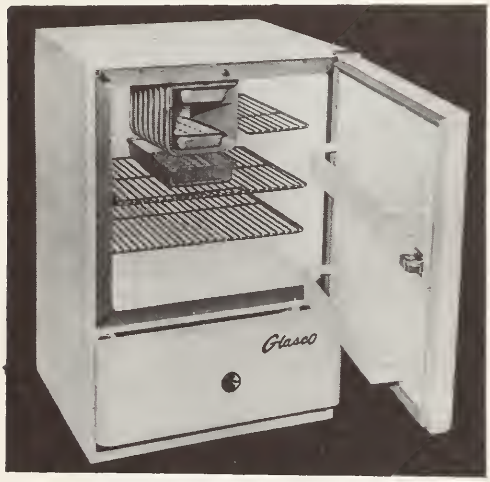
9-1. PURPOSE

The purpose of a domestic refrigerator is to provide a low temperature storage place for foods and beverages. The low temperatures made available enable people to have fresh fruits,

vegetables etc. at less expense. It enables a constant supply of ice, and will keep frozen foods for long periods.

9-2. CLASSIFICATION

Cabinets are classified on many different bases: The net volume of the cabinet, right or left door opening design, with or without a frozen food compartment, etc. The main parts of a refrigerator are the frame, the inner shell, the outer shell, the insulation, the door, the cooling coil, the condensing unit, and the hardware.



9-1. A table height refrigerator. It is used in apartments, recreation rooms, etc. (Glascock Bros. Mfg. Co.)

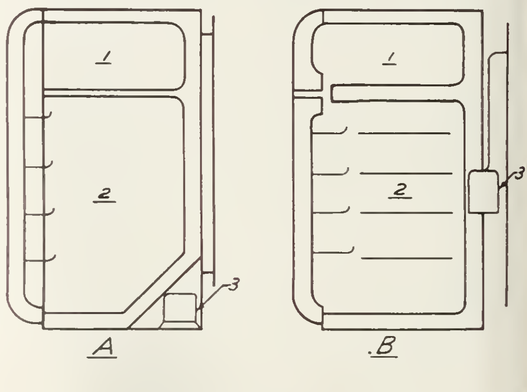
9-3. CABINET SIZES

Manufacturers have two popular ways of classifying cabinet styles and sizes. One way is by the door design which may be a single door, double door, or multiple door. In any case, the cabinet is usually specified as to the content capacity in cubic feet. This usually varies from the smallest of about 4 cubic feet up to sizes of 15 cu. ft. In the very large cabinets, the number of doors usually increases with the capacity of the unit.

The size of the cabinet may be classified in two ways: In either gross cubic feet, or net cubic feet. The gross cubic contents are measured by multiplying the three interior dimensions together. The net cubic feet (usable cubic feet) is this volume less the space occupied by the cooling unit. This latter volume is usually the one used when comparing cabinets.

9-4. LOCATION OF CONDENSING UNIT

Manufacturers have differed as to the location of the condensing unit in self-contained cabinets. There seems to be definite reasons for the positions that the condensing units have occupied in the cabinet. Manufacturers placing the condensing unit in the bottom of the cabinet have claimed that the condensing unit is more efficient because it is in the coolest part of the room. Also, that the shelves of the cabinet are more convenient being on a higher level and within the housewife's ready reach. Manufacturers who have placed the condensing unit at the top of the cabinet claim that this arrangement makes the cabinet more efficient because the heat radiated from the condensing unit does not have to travel past the refrigerated



9-2. Two modern cabinet designs. A. The compressor unit at the bottom rear; B. The compressor unit at the back of the unit. 1. Freezer compartment; 2. Regular storage space; 3. Motor-compressor.

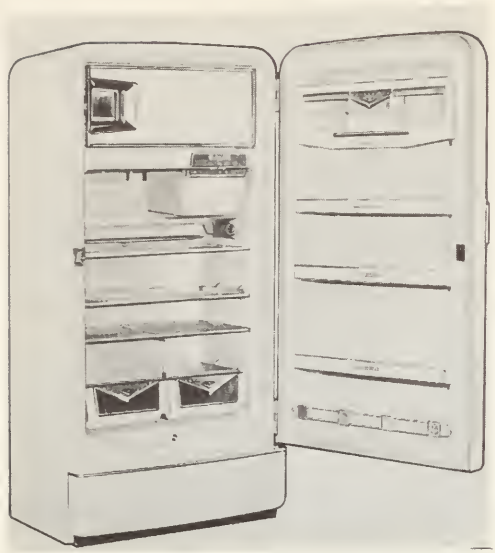
9-3. A single door domestic refrigerator. Note the storage space in the door. This refrigerator has an automatic defrost.
(Kelvinator Div., American Motors Corp.)

portion of the cabinet; therefore less heat will be transferred from the condensing unit back into the cabinet. In some cabinets the condensing unit and the cooling unit, are combined as a single unit that is placed on top of the cabinet. This makes for considerable simplicity in assembly and, perhaps, in servicing of the unit, particularly if the unit has to be removed from the cabinet for service purposes.

The latest practice is to mount the unit in the bottom rear of the cabinet or in the back of the refrigerator wall, Fig. 9-2.

From the standpoint of the efficiency of a refrigeration unit it will probably be best to remove the condensing unit from the cabinet entirely and either place it in the basement, or in some place that is normally cooler than the kitchen. One manufacturer

9-4. A double door domestic refrigerator having full length doors on both the freezer and the normal storage compartment.
(Kelvinator Div., American Motors Corp.)



9-5. A one door cabinet design with an across the top freezer.
(Hotpoint Co.)

placed the condensing unit in the basement at no extra charge because it was realized that extra satisfaction would be received by the owner from this type of installation. The consensus of opinion is that the purchaser of a cabinet is usually more interested in the convenience of the cabinet and the convenient

9-6. A two door cabinet design.
(Hotpoint Co.)

elevation of the shelves, than in the very small increase in efficiency that may be obtained by any particular location of the condensing unit. Figures 9-3, and 9-4, illustrate two popular cabinet designs.

Another across the top cooling coil model is shown in Figure 9-5. This is a 11.6 cubic foot cabinet (2.2 in the freezer and 9.4 in the fresh food space). A two door cabinet is shown in Figure 9-6. It has a cooling coil for the lower compartment too.

A cabinet which has revolving shelves is shown in Figure 9-7. The door shelves are adjustable. A two door

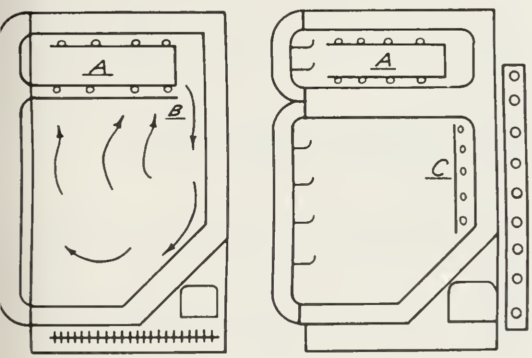
9-7. A refrigerator cabinet with revolving shelves. The center post permits the shelves to revolve and also enables the shelves to be adjusted for height.
(General Electric Co.)

cabinet with the freezer in the bottom compartment is shown in Figure 9-8. This cabinet has a foot latch to operate the lower door.

In some of the absorption type machines the refrigerator mechanisms are located on the side of the cabinet due to the ease with which this mechanical arrangement may be connected with the cooling unit in the cabinet. In the more or less conventional

compressor condensing type, the cooling unit is either placed in the upper left hand corner of the cabinet, or in the center of the cabinet. In any event, the cooling unit is usually placed at the top in order to provide for the best refrigeration of the air and consequently for the interior of the cabinet and its contents.

9-8. A refrigerator cabinet with the freezer located in the bottom. Note the foot pedal which is used to open the freezer door.
(General Electric Co.)



9-9. Cooling coil arrangement in typical domestic cabinets which provide frozen food storage. A. Frozen food coil; B. Duct to allow cold air to enter regular storage compartment; C. A separate cooling coil for the regular storage space; this is a non-frosting coil.

9-10. A domestic refrigerator cabinet. A modern kitchen refrigerator which provides both a frozen food compartment, a normal food storage and a large crisper (high humidity) at the bottom.
(Kelvinator Div., American Motors Corp.)

9-5. COOLING COILS

Many cooling coils are in the form of a shelf across the top of the cabinet.

Those cabinets with frozen food compartments have several arrangements for cooling the regular section of the cabinet. The cabinet construction is different for each type cooling coil. Some models use a wrap around freezer coil, which is commonly made of aluminum. This freezer is bolted to the roof of the inner liner and it has a metal or plastic tray shelf mounted beneath. Controllable air ducts along the sides and back of this shelf allow cold air to settle to the regular portion of the cabinet to refrigerate it, Fig. 9-9. The other type cabinet construction insulates the frozen foods space from the regular space and a separate coil is used to cool this space. The separate coil is either a secondary coil or is in the regular cycle as an overflow coil using a suction pressure valve, or it may have a separate condensing unit.

9-6. DESIGN FEATURES

These cabinets have two major characteristics:

a. More ice cube and frozen food space is provided

b. More refrigerated space compared to the same external dimensions of the cabinet

The growing popularity of frozen foods has caused refrigerator manufacturers to redesign the interiors of their cabinets to enlarge the cooling coils to make more space available for frozen food storage. Some are using as

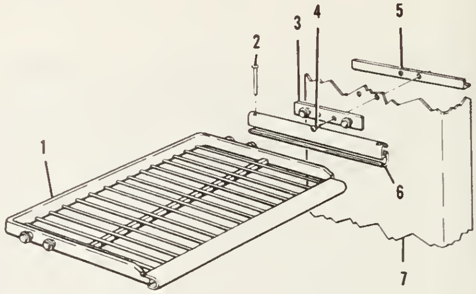
9-11. A revolving refrigerator shelf. The center column supports the shelf and also provides for different shelf heights.
(General Electric Co.)

much as 25 per cent of the internal volume for this type of service. To accommodate high container storage and to use the interior volume more efficiently, most of the cooling coils are now mounted in the middle top of the interior. Several companies are using a flat cooling unit (shelf effect) to provide this extra service. See Fig. 9-10.

9-7. SHELVING

Present day shelving is made from stamped steel or aluminum. The shelves are either mounted on small non-corroding wheels (nylon) or are semi-circular in shape to permit revolving, Fig. 9-11.

The roll out shelves must be designed to move easily even though loaded and they must also be made to prevent tipping as they are moved out of the refrigerator, Fig. 9-12.



1 Shelf with rollers
2 Stop pin
3 Stationary roller assembly
4 Screw
5 Stiffener-tapping plate
6 Shelf roller channel
7 Liner

9-12. A refrigerator roll-out shelf assembly.
(Franklin Mfg. Co.)

Most refrigerators also have trays or bins for the storage of meats (near the coil) and for fruits and vegetables. These trays or bins usually have glass plate covers. Providing shelves in the door was originated by the Crosley Shelvador in the '30s. Many cabinets now have recessed doors with devices built in to hold beverages, eggs, cheese, butter, etc.

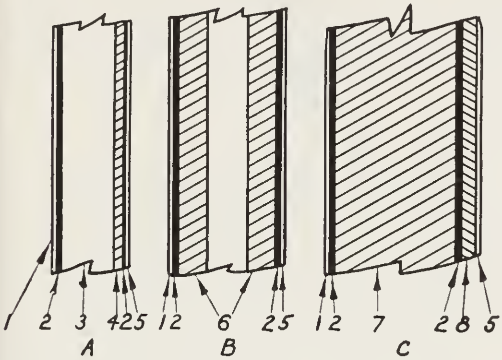
9-8. REFRIGERATOR CABINET CONSTRUCTION

The inner shell of the refrigerator is usually made of one piece of sheet steel. It is formed in a large press. Most outer shells are made of several pieces of steel spot welded or seam welded into one rigid shell. The outer shell has a frame welded to its interior. The shell is painted with a durable white paint or is porcelain finished. The

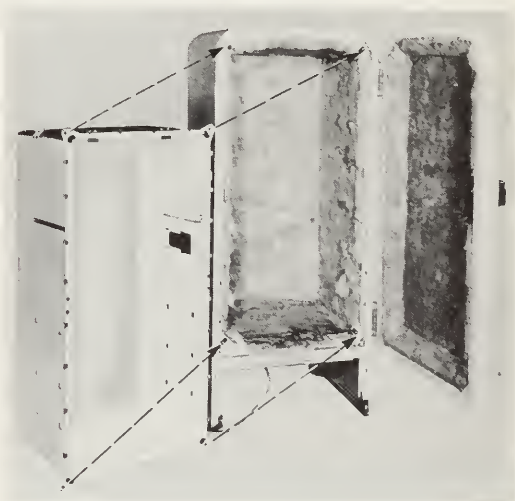
inner shell is also fabricated from sheet steel. It is usually finished with porcelain. The inner shell has provisions for mounting the cooling coils and shelf brackets.

9-9. INSULATION

The common use of the ice-box has shown the advantages of a well-insulated cabinet. In the development of the ice-box various insulating materials were used, naturally some were found to be better than others. In the electric refrigerator, because the cost of refrigeration is largely the cost of pumping out heat that leaks into the box, the matter of insulation becomes a very important one. Tests have shown that the greatest heat load is the heat transfer to the refrigerator through the insulation. As discussed in Paragraph 1-39, there are three ways in which heat may be conveyed from one point to another. Care must be taken in the design of the refrigerator cabinet that heat is not transferred into the cabinet by any of these three methods. Heat is kept from leaking through the cabinet by lining it with some heat insulating substance such as cork, corrugated paper, glass wool, fiber glass, wood fibre, aluminum foil, or other insulating material. Cabinets are constructed with metal or wood frames and have solid steel inner and outer shells. Insulation is inserted between the two surfaces in slab or package form, Fig. 9-13. The greatest insulation problem is moisture. Many insulations are made with equal insulating powers when new, but as they age, they may become moisture-laden and lose much of their insulating ability. To prevent this, all the insulations are sealed water-tight before and after putting them in the cabinet. The problem is to prevent air from coming in contact with the cold insulation or inner surface and causing condensation there. If this moisture does collect, it will eventually ruin the cabinet. Manufacturers seal the insulation with hydrolene (a petroleum by-product) which is an odorless tar. After the insulation is in place, all the



9-13. Three different refrigerator wall constructions. A. Older type; B. Modern ice box; C. the usual electric refrigerator box insulation. 1. Inner lining usually steel with porcelain finish; 2. Cardboard backing or a coating of odorless asphaltum; 3. Dead air space; 4. Hair felt or equal; 5. Exterior of steel usually lacquered; 6. Cork or hair felt; 7. Slab insulation wrapped in water-proof paper; 8. Veneer or paper backing.



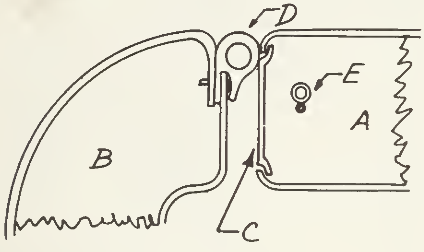
9-14. A cabinet with the inner shell and the door liner removed. Note how the insulation forms into the space. (Hotpoint Co.)

crevices are filled with this material. The insulation thickness varies from two to four inches with three inches being a good value. Modern insulations are made to fit the space accurately and are non-odorous. See Fig. 9-14.

A comparatively new development in insulation consists of successive thin metal sheets placed $\frac{1}{4}$ to 3/4 in. apart. Metals to be used for this purpose must not corrode readily, must have structural strength, and must reflect heat well. Steel, zinc, lead, copper, tin, aluminum, as well as a number of alloys, fill these requirements if processed correctly. Steel and aluminum are the metals most commonly used.

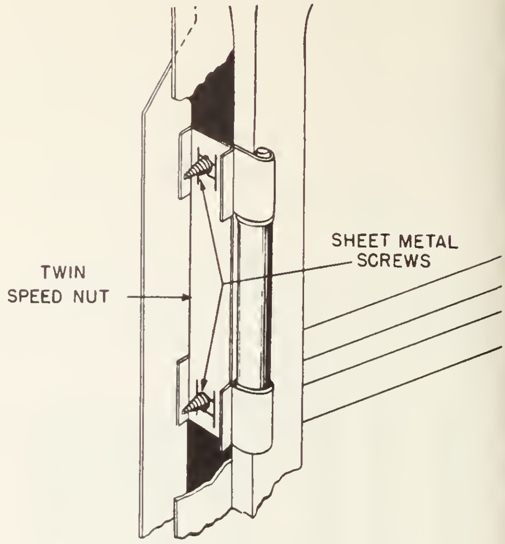
The exceptional degree of reflectivity of heat possessed by metal surfaces reduces the radiation through the alternate layers of air and metal, and the narrow air spaces decrease convection and conduction.

This type of insulation may be used in any kind of service at almost any temperature: In refrigerators at low



9-15. A typical refrigerator door construction. A. Cabinet wall; B. Door; C. Plastic breaker strip; D. Rubber gasket; E. Suction line and capillary tube.

temperatures, in residences at ordinary temperatures, and in manufacturing processes at high temperatures. It is claimed that less wall thickness is required for an equal insulating value of metal insulation than with the usual materials used for these purposes. See Chapter 21 for tables giving the insulation value of materials commonly used in refrigeration.



9-16. A modern refrigerator door hinge. (Crosley Div., Avco Mfg. Corp.)

To prevent heat transfer by convection, such as would occur if air is allowed to circulate in and out of the cabinet, the door joints and other openings to the box are carefully sealed with rubber seals, such as door seals, or with sponge rubber in places where tubing and other lines are led into the cabinet. Radiation of heat into the box is lessened to some extent by coating the outside, and the inside lining of the cabinet with materials that do not readily absorb or radiate heat. The porcelain surface seems to be quite satisfactory from both of these standpoints. White enamel lacquer also is satisfactory.

9-10. DOORS

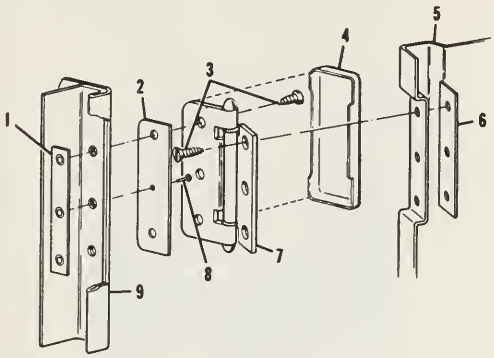
The refrigerator door at one time was a composite structure of wood and insulation with exposed hardware. Later models used a metal interior to the door. Felt gaskets were used to seal door joints.

The all-metal door was the next development. It was used with plastic strips mounted between the porcelain finished interior surface and the other part of the door. The door was built to recess into the opening.

Refrigerator doors are now built to cover almost the entire front of the refrigerator, See Fig. 9-15.

The inner liner of the door is usually recessed to provide for space for small shelves. Small vent holes are provided in the door to release entrapped moisture to keep the inner liner from sweating. Some doors have built-in butter cavities. As most of these use a small heating element an electric cord must be run from the cabinet to the door on the hinge side.

Some cabinets use a plastic as the inner liner of the door.



1 Hinge base tapping plate
2 Fiber spacer
3 Door hinge screw
4 Hinge cover
5 Cabinet door outer shell
6 Hinge wing tapping plate
7 Hinge assembly
8 Tapping plate retainer pin
9 Cabinet outer shell

9-17. A dismantled cabinet hinge showing the various parts.
(Franklin Mfg. Co.)

9-11. HARDWARE

Hardware includes the door latch and hinges. The early latches and hinges were made of brass and were fastened to the cabinet and doors with brass wood screws. In the 30's most of the hinges were made of die cast zinc alloys and used steel pins. However the castings wore rapidly and soon caused doors to fit poorly.

The modern hinge is fastened to steel plates that are welded to the shell by using machine screws. Sealed ball bearings are mounted into the hinge to promote easy door operation. Because modern doors are larger and because most of them have built-in shelves the strength and durability of the hinges is important.

9-12. HINGES

Present day hinges are usually made of steel or extruded aluminum, corrosion proofed to prevent rusting. That part of the hinge which is bolted to the cabinet and door is hidden under breaker strips. The exposed parts of the hinge are shaped and finished to blend in with the general design of the cabinet, Fig. 9-16.

That part of the hinge fastened to the cabinet is called the hinge, that part fastened to the door is called the hinge butt. The joining piece is called the pin. The hinge is usually adjustable on the cabinet. Shims are used under both the hinge and the hinge butt to adjust the distance between the door and the frame. Fig. 9-17.

The hinges are usually concealed after installation by using covers, Fig. 9-18.

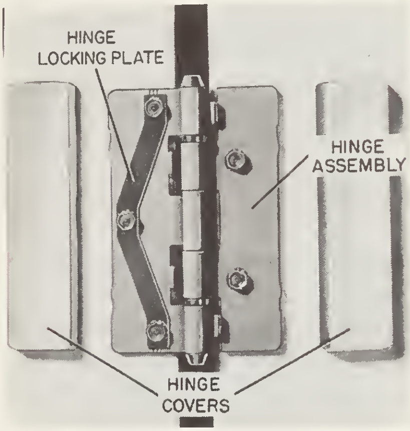
9-13. LATCHES

The original door latch was a lever that fitted into a tapered slot in the cabinet fitting. The wedge action obtained forced the door tightly against the cabinet. To operate these latches required considerable effort.

Latches were then constructed with a spring operated latch bolt that maintained a constant tension on a roller equipped bar and the spring pressure against a tapered cabinet fitting held the door tightly closed.

The latch consists of the handle and latch while that part that is fastened to the cabinet is called the strike.

One company eliminated the latch

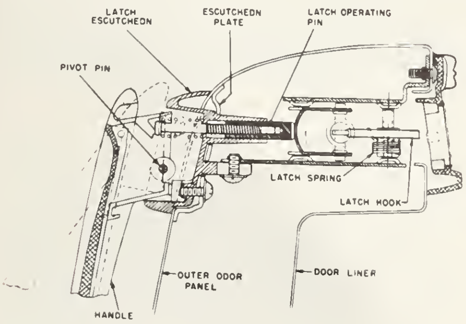


9-18. A cabinet hinge with the covers removed. (Hotpoint Co.)

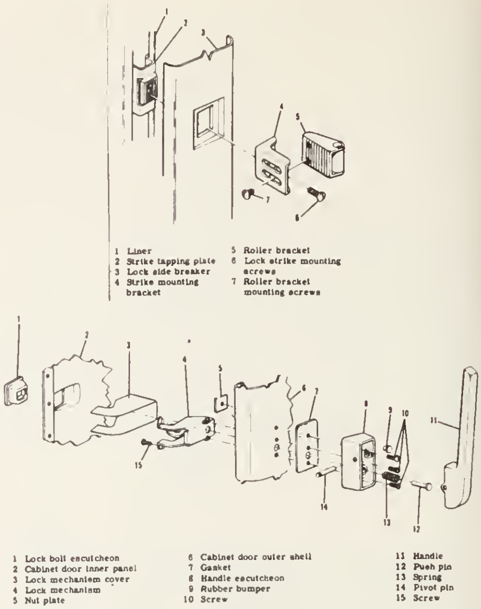
by inserting a large number of small permanent magnets in the door gasket. These magnets hold the door tightly to the door frame.

The strike is usually adjustable in two directions.

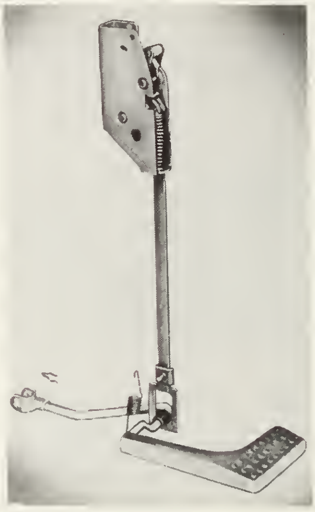
The handle is removed by removing the latch cover on the door liner or by



9-19. A refrigerator door latch mechanism. (Crosley Div., Avco Mfg. Corp.)



9-20. Exploded views of a door latch and a door strike. (Franklin Mfg. Co.)



9-21. A foot pedal latch mechanism. (General Electric Co.)

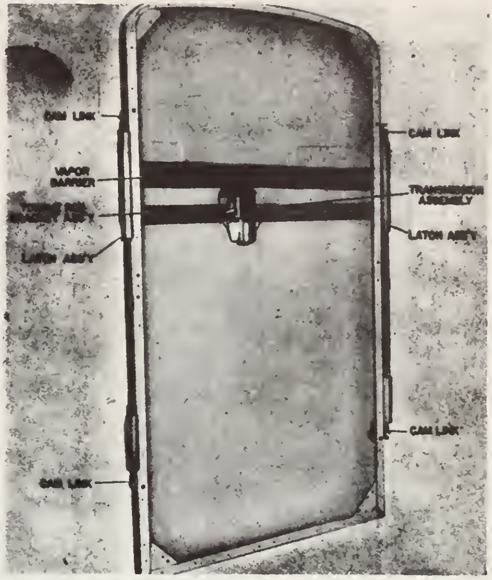
removing the complete liner.

Fig. 9-19 illustrates a door latch with a horizontal handle. A vertical handle door latch is also in common use. Fig. 9-20 shows an exploded view of one of these latches and the strike that it connects to on the door frame. A foot operated door latch is shown in

Fig. 9-21. This mechanism eliminates stooping and enables one to open the door even though both hands are full.

One company has a refrigerator which has a cabinet door that opens from either side. See. Fig. 9-22. If the handle is moved to the right, the right side of the door opens. If the handle is moved to the left, the left side of the door opens. This operation is made possible by using a double set of hinges with the hinge pins removed by the latch mechanism on one side to allow that part to become the latch and strike while the other edge of the door has a similar mechanism but the hinge pins stay in place and act as a hinge. Fig. 9-23 shows the interior of the door with the double latch mechanism.

9-22. A refrigerator cabinet equipped with a door that can be opened from either side. An articulated latch and hinge mechanism is used.
(Philco Corp.)



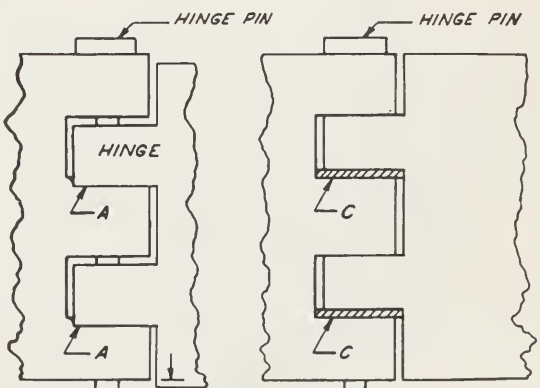
9-23. A cabinet door with the liner removed to show the articulated mechanism that enables the door to be opened from either side.
(Philco Corp.)

9-14. HARDWARE REPAIRS

Hardware must be repaired when replacement parts are not obtainable.

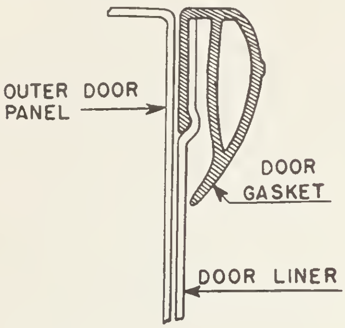
An emergency repair for hinges that have worn and caused the door to sag is to dismantle the hinge and after cleaning and filing the worn surfaces flat, insert washers to replace the wear. Fig. 9-24. The hinge pin holes may also wear elliptically. This wear can be repaired by either drilling the holes larger and inserting larger pins or inserting steel sleeves.

Broken die cast parts can be successfully repaired by gas welding if special die cast filler rods are used. A sand or asbestos paste mold should be



9-24. Repairing a worn refrigerator cabinet hinge. A. Worn surfaces; B. Sag; C. Inserted Washers.

made to hold and align the parts during the welding operation. A successful



9-25. Door seal gasket details.
(Crosley Div. of Avco Mfg. Corp.)

weld can only be made if the plating is removed around the welded portion. The parts can be replated after finishing.

Replacement springs can be made by heating spring wire to a low cherry red, cooling very slowly (in sand or asbestos) shaping the spring, heating the spring to a dull cherry red, quenching (dipping) in cold water, then carefully and evenly heating it to a purple (blue) color, quenching it again. A little experimenting may be necessary with the temperatures to which the metal is heated, as spring wires vary in their carbon content and properties.

9-15. GASKETS

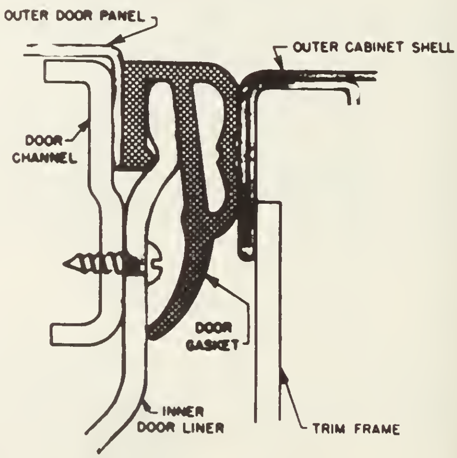
It is necessary to have an air-tight joint between the door and the cabinet. A flexible shim must be used to compensate for any slight out of line parts. Cross sections of modern refrigerator door gaskets are shown in Fig. 9-25.

Originally strips of felt were used, but rubber tubing with attaching a strip has been popular for years. Some of the rubber tubes were made with a rubber foam fill to provide more resiliency. However, natural rubber will wear quickly in the presence of oil and fats and these gaskets have to be replaced frequently. Coating the rubber with a synthetic rubber gave the gaskets a much greater life. Some of the gaskets are made of flexible plastic that does not deteriorate when coated with oil or fats.

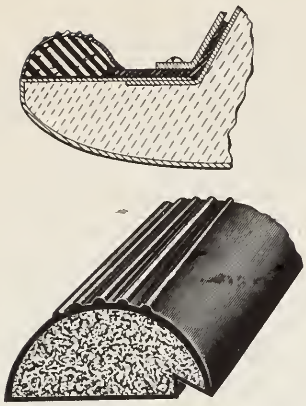
Gaskets were originally tacked to the door frame, but they are now designed to clamp into the door in the space between the inner and outer shell, Fig. 9-26.

To replace gaskets, it is usually necessary to remove the door from the cabinet and then remove the breaker strip from the door, or in some cases remove the inner liner. Cloth or felt pads should be used to hold the door to prevent chipping and/or scratching.

Replacement gaskets are usually available. A gasket similar to the worn one may be obtained or one may use a replacement gasket. The replacement gaskets may either clamp in place similar to the original, or they may be fastened by using adhesive. See Fig. 9-27. Because the gasket bead is the part that wears first, it only is removed and the new gasket bead is installed using an adhesive. The lip of the replacement gasket fits over the original gasket that remains on the door.

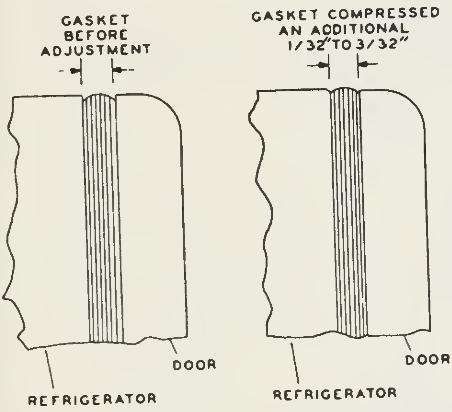


9-26. A door gasket installation. Note the air pocket which acts as a pneumatic cushion.
(Crosley Div. of Avco Mfg. Corp.)



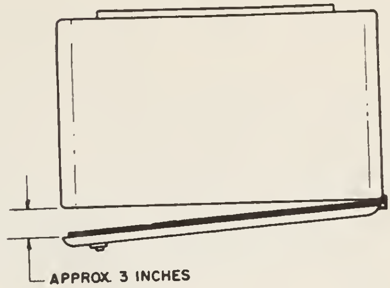
9-27. A replacement gasket that is fastened with an adhesive. The bead only of the old gasket is removed, adhesive is applied and the replacement is installed with the lip placed over the old gasket.
(Jarrow Products Inc.)

Gasket joints must be leak proof. The door must be carefully adjusted to permit easy operation and still provide a tight joint. Fig. 9-28 shows correct gasket adjustment to provide a good joint. To obtain this fit, the hinges should be adjusted first. The shims



9-28. The correct amount a typical gasket should be compressed to provide a leak proof joint between the door and the cabinet.
(Philco Corp.)

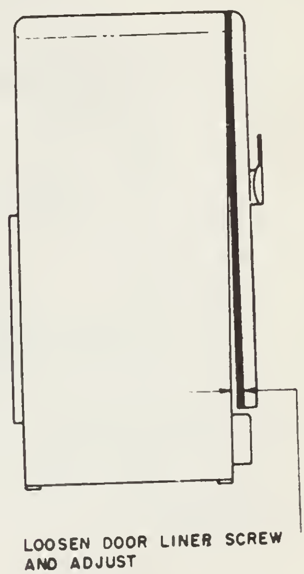
should be arranged until the hinge edge gasket contacts the cabinet when the door is in approximately the position shown in Fig. 9-29. The gasket should touch the cabinet evenly the full length of the door.



9-29. The position the door should be in when the gasket touches the cabinet evenly for its full length on the hinge edge.
(Philco Corp.)

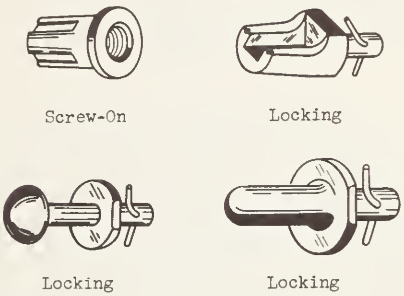
If the latch side of the door does not contact the cabinet evenly, it usually means that the door is warped. This mis-alignment can usually be remedied by loosening the door liner screws, straightening the door, and then tightening the screws, Fig. 9-30.

One method of testing a door gasket fit is to use a strip of paper. Place this paper at the door frame, close the door and if the paper resists being



9-30. When the latch side of the door does not contact the cabinet evenly, the door can be adjusted by means of the door liner screws.
(Philco Corp.)

pulled out the gasket is tight. However because this paper is about .005 inches thick, a better way to test for leaks is to place a light bulb (75 or 100 watts) on the front center shelf. The light cord should be as small as possible. With this light one can detect openings in the door joint as small as .001 inches. See Paragraph 10-16, page 256.



9-31. Various types of shelf supports. (General Electric Co.)

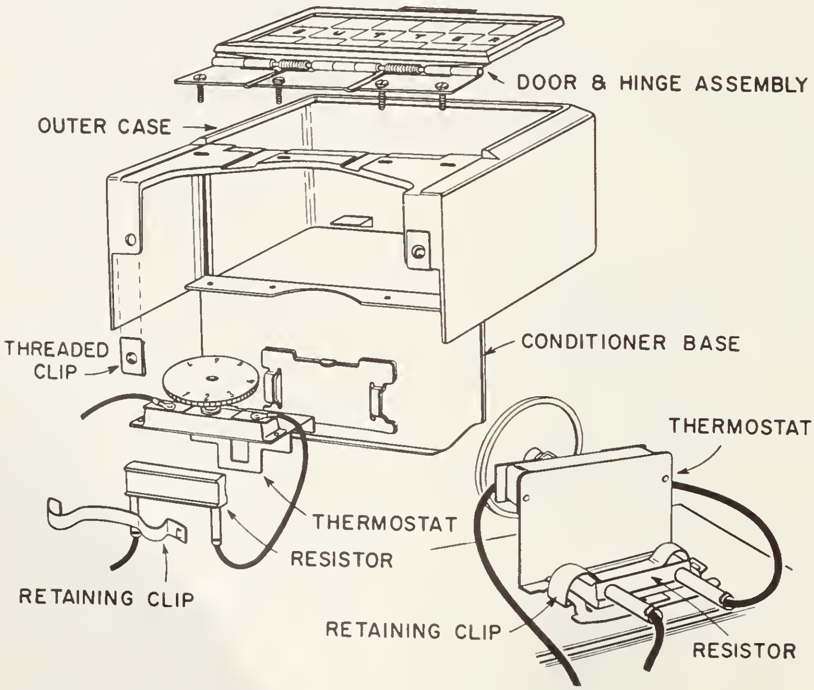
9-16. ASSEMBLY DEVICES

The original wood cabinets were assembled by means of gluing and the use of brass wood screws.

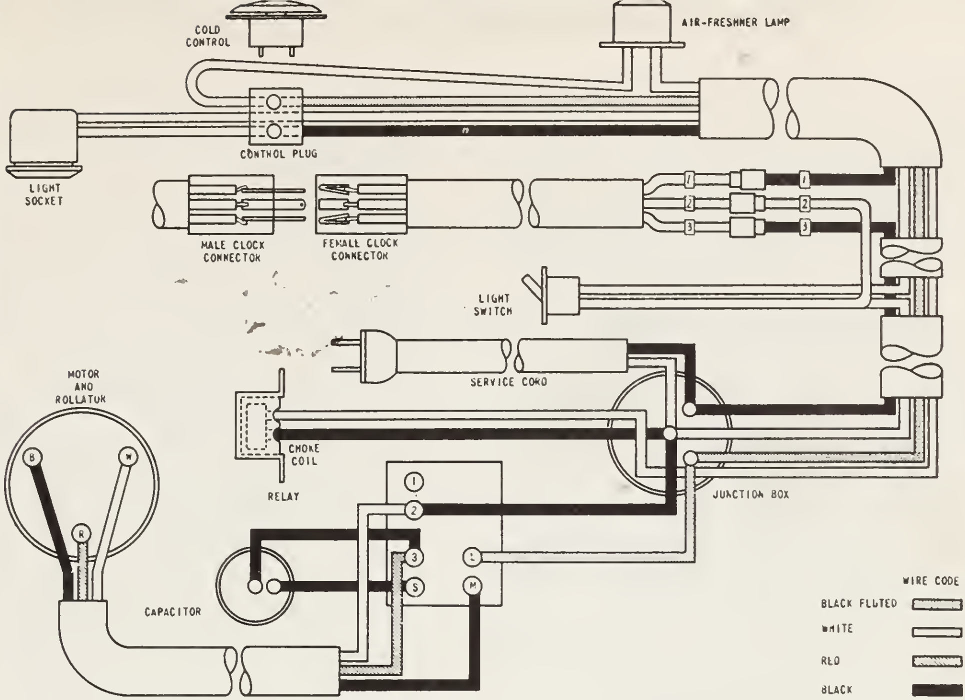
The modern metal cabinet uses a great variety of assembly devices. Where great strength is needed and for parts which need not be removed, spot welding is used. For example, the plates to which the hinge and hinge butt are attached by welding. The frame of the cabinet that supports the motor-compressor is usually welded in place.

The hinge parts and the latch parts are usually held in place by counter sunk machine screws. Some of these screws use lock washers to help make a permanent adjustment.

Small parts may be held in place with sheet metal screws. In tightening sheet metal screws care must be taken as a slight excess in tightening torque



9-32. Details of a butter conditioner. The space is heated with a small resistor which is controlled by a thermostat. (Hotpoint Co.)



9-33. A wiring diagram showing the electrical connections for air freshening lamp. (Norge Sales Corp.)

will strip the threads in the sheet metal. The screws are made of hardened metal.

Many cabinets use quick fasteners. These devices are in great variety. They are usually made of spring steel and use hard sharp edges to hold them in place.

The assembly devices that hold the shelf brackets are usually of a spring loaded type that can be inserted from the inside of the liner and are self clamping and locking. See Fig. 9-31.

9-17. ACCESSORIES

Many devices have been created to make the refrigerator more useful. Some of these accessories are:

1. Cabinet Light
2. Butter Conditioner
3. Crispers
4. Wire baskets
5. Beverage holders including built-in units.
6. Egg nests
7. Storage bins
8. Deodorizers
9. Thermometers

The cabinet light is usually a 25-watt bulb mounted in the rear of the cabinet. It is a 110 volt light, controlled by a spring activated switch that can only close the circuit when the cabinet door is open. This switch is usually located near the bottom rear hinge of the door. The wiring is in the same harness as the thermostat wires and the wires connect into the main circuit at the junction box (usually the relay).

The butter conditioner is a small cavity built into the cabinet liner or the door liner. It usually has a very small heating element that maintains the butter at a plastic temperature (about 50 F. to 60 F.) The wiring to this conditioner connects into the main circuit at the relay and it is parallel with the thermostat, Fig. 9-32. It only operates when the unit is running.

Crispers, or covered containers in the refrigerator are used for storing vegetables, fruits, and meats. They

prevent drying of the food from the dehumidifying action of the cooling coil. Newer designs use glass shelves as the cover for the containers and the containers slide out on racks. Some models use built in doors (metal) to seal in this space.

For convenience of storing, some refrigerators have wire baskets to hold certain foods for ease of handling. Some of these baskets are suspended under the shelves to save space.

Originally special glass containers or plastic containers were used to hold water or fruit juices. This practice is still being followed but some units have built in beverage containers. These plastic containers are built into the door. An outside beverage tap may be provided. The cooled beverage can be obtained without opening the cabinet door.

There is an increase of specially built shelves and baskets shaped to efficiently hold standard shaped articles such as bottles, eggs, oranges, etc. The orderly arrangement insures more storage space and convenience.

If there is any non-refrigerated space in the cabinet (front lower section) a storage bin is frequently provided. These bins are usually used for such items as potatoes, onions and other warm temperature storage.

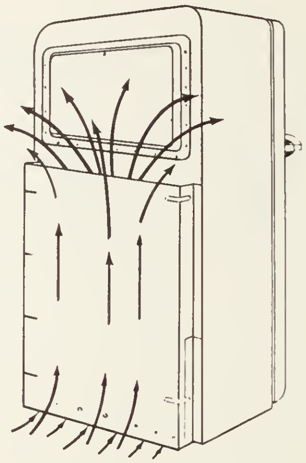
Deodorizers are volatile chemicals (solids) that seem to remove refrigerator odors. However the process is mainly an odor neutralizer. Charcoal filters seem to be the most effective means of removing odors.

A small thermometer mounted either with a hook or by using a small magnet will indicate temperatures in any desired part of the refrigerator.

9-18. ICE CUBE TRAYS

Practically all refrigerators provide facilities for making ice. The ice is usually made by filling shallow trays with tap water. The trays have grids (about $1\frac{1}{2}$ in. squares) that shape the ice into easily handled cubes.

The trays were originally made of copper, tin coated. Aluminum trays have been used since the 30's. Rubber, stainless steel and plastic trays have also been used.



9-34. The air circulation flow over the condenser of a refrigerating unit mounted on the back of the cabinet. These air passages must be kept clean. (Kelvinator Div., American Motors Corp.)

The use of ice cube trays presents two problems. First the trays become frozen to the shelf and are occasionally difficult to remove. A heated flat knife will usually loosen the tray. Some companies have built in levers that permit pressure to be brought against the tray to loosen it. A sharp tool may cause a puncture of the refrigerant liner and should never be used. Second, the ice cubes are difficult to remove from the tray. The tray may be heated by running either cold or hot water over it until the heat travels through the tray and grid and loosens the cubes. The use of rubber trays, plastic trays, and flexible trays permits the cubes to be removed without difficulty. One company uses a strongly built grid with a lever that easily frees the grid from the tray and frees the cubes at the

same time. Some trays have a wax finish which makes it easier to remove the ice cubes.

One company has produced an automatic ice cube maker that fills itself, freezes the cubes, frees the cubes automatically, and then dumps the cubes into a basket. The operation continues until the basket is full. See Chapter 18 for an explanation of commercial automatic ice cube makers.

The ice formed in ice cube trays is usually foggy, translucent ice. The foggy appearance is due to the release of air from the water as it freezes. Clearer ice may be produced by first boiling the water, and then allowing it to cool to room temperature before putting it into the cooling trays.

9-19. ULTRA VIOLET LAMPS

To minimize bacteria growth and to prevent transfer of bacteria (odors and mold) from one food to another in a refrigerator cabinet, some companies have installed ultra-violet lamps in the refrigerated compartments. Such lamps are made by most of the electric lamp companies. They burn continuously while the refrigerator is electrically connected.

9-20. FINISHES

The exposed parts of the cabinet must be carefully conditioned and finished for appearance and durability. Since the use of metal in the cabinets, most of the cabinets have used a porcelain interior (inside of the liner) and a lacquer or enamel paint on the outside of the cabinet and door.

Because porcelain is a relatively expensive finish only the more de luxe cabinets are finished with it as an exterior finish. Some baked enamels today are virtually as durable and sanitary as porcelain and because they are chip and crack resistant, they are being used on many refrigerators.

Some of the earlier white enamel finishes had a tendency to discolor (turn yellow) after several years of service but present day finishes are virtually immune to this fault.

9-21. LACQUERS AND ENAMELS

The metal to be finished must be carefully prepared before being painted. All dirt, grease, alkalies, dust, etc. must be removed from the metal. Rust spots must be removed. The temperature and humidity in the paint room must be carefully controlled according to the paint manufacturers' recommendations.

The paint is sprayed on the metal and the units are then baked in special drying ovens or bins. The drying devices are usually heat lamps.

9-22. PORCELAIN

The porcelain process is a method of coating the metal with a white opaque glass. The process consists of first thoroughly cleaning the metal and then fusing black opaque glass to this metal at a high temperature. This black finish is porcelain with an iron content that has a coefficient of expansion, the same as that of the metal and of the white porcelain. The white porcelain is then bonded to this black porcelain at a high temperature and a smooth-glassy finish is obtained. The porcelain has one disadvantage of being brittle and it can be chipped easily. Furthermore, it is extremely difficult to repair.

9-23. ELECTRICAL CONNECTIONS

Practically all refrigerators are electrically connected to the house electrical system by a flexible electrical extension cord equipped with a two-prong plug. This plug is inserted in an outlet and the power supply is

complete. To insure extra safety a separate ground wire can be installed between the refrigerator steel frame and a conduit or a water pipe. It is important that the extension cord be put in such place that it cannot be kinked sharply or pinched. In all electrical refrigeration hook-ups it is of the utmost importance that the refrigerator motor have the same characteristics as the power line. The frequencies must be the same, that is, 60 cycle, 25 cycle, etc. The voltage must be the same, 110, 220, 32-volt. The phase must be the same, single phase, three phase, etc. Single phase motors are used almost exclusively for domestic refrigerators. Sufficient current must be available for motor consumption and the voltage must be up to the voltage required by the motor. To check up on these values an A.C. ammeter and voltmeter may be used. The voltage at the outlet should be checked with the unit running and off. A voltage drop of over 15 volts will necessitate electrical service corrections. In most cases it may be advisable to install a new circuit for the refrigerator rather than use the supply already available in the kitchen which in many instances is already overloaded.

9-24. LOCATION OF THE REFRIGERATOR

The location of the refrigerator is mainly determined by the convenience of the cabinet to the other devices in the kitchen. However, some thought should be given to the following factors:

1. The refrigerator should not be exposed to sunlight because the sun's rays will add to the cost of operation and may discolor the exterior finish of the refrigerator.
2. The refrigerator must be close to an electrical outlet as overloaded or lengthy electrical lines reduce the line voltage to dangerous levels.
3. It must be located to provide good air circulation through the condenser. Figure 9-34.

9-25. CARE OF THE REFRIGERATOR

In the operation of any domestic refrigerator, the owner should be instructed not to allow the door to remain open. Due to the great difference in temperature between the inside of the cabinet and the room temperature, convection currents will be set up as soon as the door is opened. This will bring a great deal of heat into the cabinet; therefore, the door should be open only when removing articles from, or placing articles in the cabinet.

The cabinet must be kept clean outside as well as inside. The hinges and latch should be lubricated periodically. The condenser and motor-compressor should be wiped clean at least every six months. The door gasket should be checked for tightness periodically.

9-26. DEFROSTING THE REFRIGERATOR

Another point in the operation of a refrigerator that is often neglected is the matter of defrosting the cooling unit. The housewife particularly fails to appreciate the fact that if the cooling unit is covered with frost and ice it cannot remove heat efficiently. She may even feel that the frost and ice on the unit indicate that it is operating better than it would if this accumulation were not there. This, however, is not the case. The frost and ice act to some extent as an insulator, keeping the air from flowing into the cooling unit and resulting in a higher box temperature; consequently more running or operation of the condensing unit is required in order to maintain the proper cabinet temperature. In general, the unit should

be defrosted once a week. Defrosting more often may be necessary if uncovered liquids or other moist foods are placed in the cabinet in large quantities.

Manufacturers formerly placed a defrosting switch in or near the control panel which made it easy for the housewife to defrost the refrigerator at regular intervals. A tray or pan of some kind was placed below the cooling unit before the unit was defrosted; otherwise water formed in defrosting the unit would drip on articles below and on the bottom of the cabinet.

Many present day refrigerators have automatic defrost devices. These devices are clock operated to turn on each day at a certain time (1 or 2 A.M.) Some are actuated by mechanical devices such as a ratchet controlled by opening of the door. These controls either turn on electrical heating elements to melt the frost or open a solenoid valve to send hot gas through the cooling coil until the frost is melted. See Chapters 6 and 16 for more complete information concerning automatic defrosting systems. Another reason a coil should be defrosted is that this collection of frost on the cooling unit is usually odor-laden and will permeate the food with unpleasant odor. It is essential that the frost be removed if it accumulates to a thickness of 1/8 inch; and regardless of the thickness of the frost, the unit should be defrosted and the moisture removed at least once each week.

In those refrigerators which are not equipped with a defrosting switch or in some gas-fired refrigerators, a very convenient method of removing all frost from the cooling unit is to fill the ice trays with very hot water and to repeat this until the frost has melted off the surface of the cooling unit.

Needless to say, a drip pan or a frost pan should be placed underneath the cooling unit during the defrosting process, or the cabinet will become flooded with water that drips from the unit. This tray is usually made of glass. It is advisable to remove the tray from the box except during period of defrosting because the tray hinders the circulation of cold air.

Some refrigerators that use automatic defrost devices have a drain tube that carries the moisture to a water pan located near the compressor-motor.

The cool defrost water will cool the compressor and in doing so will evaporate into the room.

9-27. CLEANING REFRIGERATORS

Refrigerator cabinets are finished with either a porcelain or a special enamel coating. The procedure to follow in the refrigerator finish depends upon which of these materials has been used. If the finish is porcelain, one must be very careful of it because of the brittleness of the glass-like finish.

To clean porcelain the same substances may be used as for cleaning glass, such as borax or any good compound which will not scratch the surface. It is imperative that for cleaning the inside of the cabinet a cleaner be used which has no odor. After cleaning, a thorough rinsing is necessary. Occasionally the interior of the cabinet becomes stained with an iron stain on the porcelain due to cracks appearing in the porcelain or at the joints. This stain can usually be removed by thorough cleansing. If this is not practical it may be covered over by using lacquer of the proper color.

One of the best solutions for cleaning the interior of a cabinet is baking soda dissolved in warm water. This solution cleans, deodorizes, and leaves no harmful residue. Harsh abrasive cleaning agents should be avoided as they may permanently injure the finish.

9-28. PATCHING PORCELAIN

When filling in cracks or chipped parts of a porcelain finish, a special porcelain patching material should be used. Because of the inherent nature of porcelain, its color shade will vary somewhat. A patching kit may be obtained with several colors. If necessary, blue ink may be added to the patching material to obtain the right shade. In doing this work it is first necessary to clean the surface to be patched quite thoroughly, warm the area of the patch, then apply the patching material with a small, fine hairbrush or air brush, being sure that the material is not too thin. After the material has dried, it should be smoothed down with water proof abrasive paper and then polished with a soft cloth, or by using rottenstone (available from paint stores) and rubbing oil.

9-29. REPAIRING ENAMEL FINISHES

Enamel finished cabinets may be repaired by using high grade enamel. Examine the damaged area carefully. All wax and rust must be removed, down to bare metal. Sand edges of the damaged area with fine waterproof paper (6/0) so the old finish slopes toward the center. This is called "feather-edging" and is done to allow the primer and finish coat to blend smoothly with the old finish. Soapy water may be used as a sanding lubricant. The surface must be absolutely dry before applying primer.

Next, apply metal primer to exposed bare metal with a brush or spray gun. The primer provides a hard surface for good adhesion of the finish coat. Allow the primer to dry thoroughly. When the primer is dry, sand lightly using 6/0 waterproof paper and soapy water as a sanding lubricant. Lightly scuff surfaces around damaged area to completely dull the old finish and blend with the primer coat.

Spray or brush on the enamel, blending new coat as smooth as possible to the old finish. Allow enamel to dry thoroughly, then sand (wet) with 6/0 paper until all edges are invisible. For a high-gloss finish rub entire surface including patched area with rottenstone and paraffin oil or rubbing oil. When desired gloss has been reached, wipe off rottenstone and oil by using moistened cloth or chamois. Paint spraying must be done in a fireproof, well ventilated booth.

9-30. CLEANING LACQUER FINISHES

When cleaning lacquer surfaces, great care must be taken to insure that the cleaning materials do not harm the surface. Gritty cleaning materials should not be used as they will scratch the surface. Rubbing, if necessary at all, should be kept to a minimum. To clean lacquer finished cabinets, solutions and materials are now on the market which have the property of cleaning and polishing the surface simultaneously. These should be applied according to the manufacturer's directions. It is recommended that the cabinet be cleaned frequently to eliminate any odor transfers from one food to another and from the cabinet to the food.

9-31. CLEANING ICE TRAYS

In certain localities where the water contains minerals and salts that have the property of discoloring aluminum or copper ice trays in the refrigerator, it is usually found that ordinary cleaning powder and soaps do not have any effect on the stain. This stain may be removed quite easily by the following process: Dip the trays in a hot solution of water and lye, then rinse the trays in pure running water. Occasionally if

this does not remove all the stain a small brush will facilitate the work. After rinsing the lye solution off the trays in the running water, it is necessary to dip the trays in a vinegar solution, which will neutralize the lye and prevent any further chemical action on the metal. Another rinsing and the trays are ready to be used again. The trays should be immersed in the lye and vinegar solutions for approximately ten minutes at a time. Never leave them any longer. Use a double immersion, if necessary, because if left in too long it is likely to remove the finish from the metal and spoil the appearance of the trays. Ordinarily use only a mild solution of soap and water to clean the trays. Then rinse with clear water.

9-32. INSTALLING A REFRIGERATOR

The sale of a domestic refrigerator to the customer should not end the dealer's responsibility. It is equally important that the installation should be carefully, accurately, and conscientiously made in order to keep the customer convinced that he has made a wise purchase.

The economy and length of service rendered by the refrigerator is greatly dependent on the proper position of the cabinet. It is of utmost importance that the cabinet be placed in the coolest convenient place where there is no chance of its being too much in the sun's rays. Another precaution of paramount importance is the ventilation.

Hermetic units do not require any special precautions because they are hermetically sealed mechanisms and require only a correct electrical connection and proper ventilation when installing them. They should be carefully leveled because of the trays, the water level in the ice cube trays and ease of door opening and closing. Usually the two front legs of the refrigerator are adjustable (screw type) to aid the leveling of the cabinet.

9-33. INSTALLING AN ABSORPTION REFRIGERATOR

The absorption types of refrigerators are involved in a different complication in reference to installing, but this is offset by the simplicity of the installation as a whole. A lead must be made from the gas line which will probably require the sanctioning of the gas company. Some city codes specify that the fuse plug opening in the refrigerant system must be vented to the outside to prevent any chance of discharging the refrigerant into the house. The absorption unit must be carefully leveled to operate correctly. Apart from these things nothing further need be done except following the general directions in the final part of this chapter.

9-34. GENERAL INSTRUCTIONS TO THE HOUSEWIFE

Before leaving the refrigerator in the hands of the housewife it is very important that she understands the uses and abuses of the mechanism. Instruct her very carefully about:

1. Keeping the doors closed tightly.
2. Leaving all liquids covered in the cabinet.
3. Cool foods before putting them in the cabinet.
4. The correct position of different foods in the box.
5. Leaving the doors open a minimum of time.
6. Methods of defrosting. Do not use an implement for removing the frost.
7. The correct use of the temperature control.
8. The proper way to cleanse the interior and exterior of the box

and the ice trays.

9. The precaution not to crowd the shelves with articles which will obstruct circulation.

If possible, leave these instructions in written form and attached to the refrigerator. Impress upon the owner that economy of operation and long life are dependent on the proper use of the unit. Leave name, address, and telephone number in a convenient place to allow a service call to be made with a minimum of trouble to the housewife.

Some people in the temperate zones feel inclined to shut off their refrigerators in winter to economize. This should not be done if it is at all possible to keep the unit running. The unit has been well balanced and has settled to its task. To shut it off will upset its operation. The pressures will build up, and when the unit is started, it will be overloaded for a period; very often oil pumping results, causing such a disturbance that particles of dirt in the system start to circulate causing trouble. Another trouble is that after the oil pumping starts, the crankcase will be low on oil and cause scoring and overheating.

Whenever a refrigerator is moved, the condensing unit should be clamped or bolted to the cabinet if it is mounted on springs or rubber supports. The shipping bolts that were supplied by the manufacturer should be kept for this purpose.

9-36. REVIEW QUESTIONS

1. Why are refrigerator cabinets insulated?
2. What is the average thickness of the insulation?
3. Why should the insulation be moisture proof?
4. What is meant by net contents of the cabinet?
5. What are the possible locations of the condensing unit?
6. Why are ice tray releasing mechanisms necessary?
7. Why must a cooling coil be defrosted?
8. How thick may the frost become before it should be removed?
9. What is a good porcelain cleaner?
10. How may one clean discolored ice cube trays?
11. Name three substances used for insulation?
12. How are cabinet doors made air-tight?
13. Name the various cooling coil locations in the cabinet?
14. Why should the cooling coil always be located near the top of the cabinet?
15. Why should liquid and moist foods be covered when placed in the refrigerator?
16. What clogs an air-cooled condenser, externally?
17. What should a distributor of refrigerators do to safe-guard his good-will?
18. Explain a good method to provide positive rear ventilation of the base-located condensing unit?
19. What happens when a refrigerator is disconnected from the current supply for 48 hours or more?
20. Why is it best to allow a refrigerator to run instead of being shut down?
21. Why should a hermetic refrigerator be installed in a level position?
22. Why must the voltage of the electrical line to the refrigerator be checked?
23. What happens to the defrost water in modern refrigerators?
24. What is the best way to check a door gasket for leaks?
25. How are most latches and strikes adjusted?

Chapter 10

CONVENTIONAL COMPRESSION SYSTEMS

The evolution of the refrigerating machine has resulted in the increase of the hermetic design and a decline in the conventional system.

However, there are many conventional systems still in use. Also the understanding of the conventional cycle is an easy step in studying the theory of modern refrigerating mechanisms.

In school training situations, small conventional systems are ideal to use in teaching the fundamentals of refrigeration to a student. All systems are reviewed for the student in this chapter.

10-1. TYPES OF COMPRESSION SYSTEMS

Many types of conventional compression systems have been designed and manufactured. However, most conventional systems have an external motor and use a belt drive. Conventional units also have a number of service valves. A flange type service valve with two service openings is shown in Fig. 10-1.

These systems can be classified generally by the type of compressor:

1. Reciprocating Compressor
2. Rotary Compressor

Each type of compressor system can be classified by the type refrigerant control used:

Reciprocating Compressor.

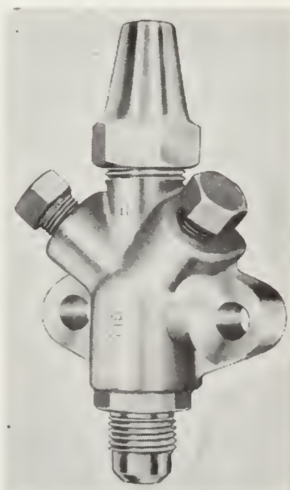
1. Automatic Expansion Valve
2. Thermostatic Expansion Valve
3. Low Side Float
4. High Side Float
   a. High Side Float and cap. tube
   b. High Side Float and wt. check valve
5. Capillary Tube

Each of these ten different systems could be classified according to the location of the condensing unit:

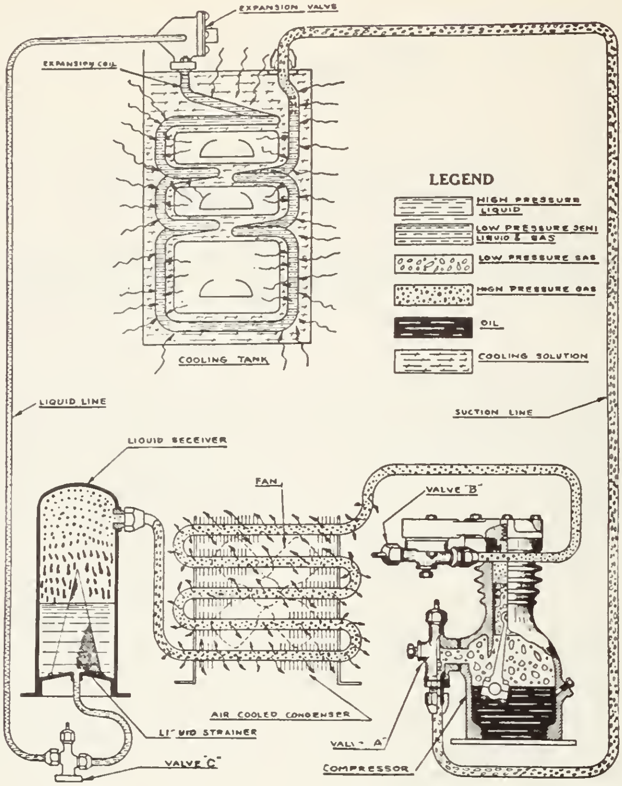
1. Top Mounted Condensing Unit
2. Bottom Mounted Condensing Unit
3. Remote Mounted Condensing Unit

10-2. AUTOMATIC COMPRESSION SYSTEMS

Many large refrigerating systems



10-1. A flange type service valve with two service openings. The valve stem is protected with a cap. A flared type tubing connection is used.
(Mueller Brass Co.)



10-2. A conventional automatic expansion valve system using a reciprocating compressor.

are manually operated and require the service of a licensed refrigeration operating engineer during all hours of operation. These engineers manually control the flow of refrigerant in the cycle and manually control the operation of the motor.

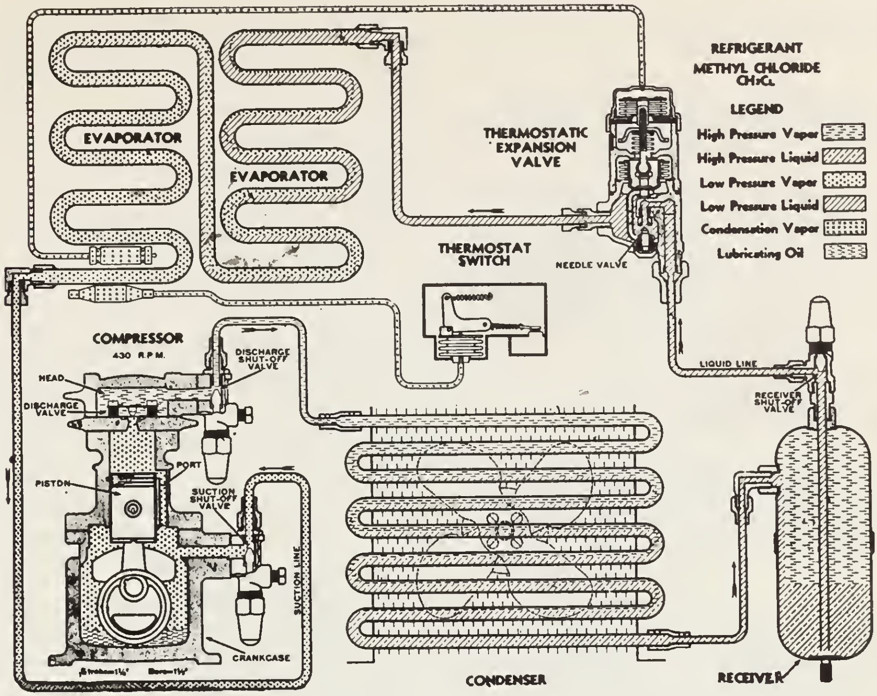
Some local codes and the National Code recommend the presence of an operating engineer at all times where a 25 ton or over capacity refrigerating unit is operating, even though it is an automatic unit.

The automatic refrigerating unit must have two automatic controls, the automatic refrigerant control and the automatic motor control. It must also have safety devices in case the automatic controls do not function correctly.

10-3. AUTOMATIC EXPANSION VALVE SYSTEMS

The automatic expansion valve systems in the domestic field have not been produced since 1935. However, many of the systems are still being used. One of the newer applications is the remote compressor type automotive comfort cooling unit. There have been several types of automatic expansion valve systems in use.

1. AXV with a reciprocating compressor
2. AXV with a rotary compressor
3. AXV with the unit in the base of the cabinet
4. AXV with the unit in the top of the cabinet
5. AXV with a brine type cooling coil



10-3. A conventional thermostatic expansion valve system using a reciprocating compressor and a thermostatic motor control.

10-4. A X V WITH RECIPROCATING COMPRESSOR

The automatic expansion valve was used with the reciprocating compressor in many installations. One of the original units is shown in Fig. 10-2.

The discharge service valve is labeled as valve B, the suction service valve is labeled A, and the liquid receiver service valve is labeled C. Notice the screen location in the liquid receiver. The discharge service valve is placed below to permit installation in a smaller space. The oil plug on the side of the crankcase is typical and is used to determine the oil level. Note that the suction line connects to the crankcase of the compressor and the intake valve is in the head of the piston. This was a popular arrangement with many early refrigerators. There are three reasons for connecting the suction line to the crank case either directly or indirectly in order that the crank case pressure will be the same as the suction pressure:

(1) it returns the oil to the crankcase as some oil always circulates with the refrigerant: (2) it simplifies the construction; (3) it maintains a controlled crankcase pressure. The brine tank cooling unit consists of a tinned copper tank fitted with sleeves.

10-5. A X V WITH ROTARY COMPRESSOR

The rotary compressor is usable with all types of refrigerant controls.

The use of the automatic expansion valve with the rotary compressor was used in the 1930's. One example was the Coldspot unit which had a top mounted condensing unit with the cool-

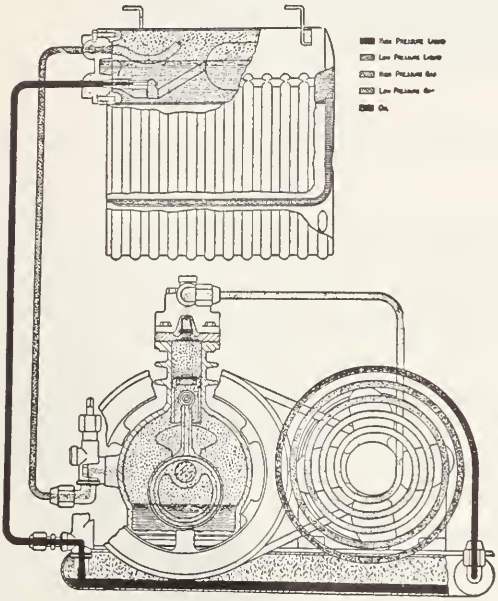
ing coil suspended from it. An automatic expansion valve was used.

10-6. THERMOSTATIC EXPANSION VALVE SYSTEMS

Some domestic systems have used the thermostatic expansion valve refrigerant control. This control provides a more efficient cooling coil operation but its extra cost has kept its use at a minimum, Fig. 10-3.

10-7. LOW SIDE FLOAT SYSTEMS

Many systems used low side float refrigerant controls in past years. This cooling coil provided a very efficient



10-4. A conventional low side float system using a reciprocating compressor. Note that the compressor uses an eccentric on a straight shaft in place of the conventional crank shaft.

cooling surface but the amount of refrigerant charge was high and the float chamber used considerable space. The low side float system has not been used in domestic refrigeration since the 30's but it is still used in some commercial and industrial refrigeration fields. A student of refrigeration should know about these systems however as the knowledge of their development and use will add to his understanding of refrigeration.

10-8. LOW SIDE FLOAT WITH RECIPROCATING COMPRESSOR

Fig. 10-4 shows a complete system.

It had a unique condenser in that it was constructed on the spiral principle, and in some models it was cooled by a fan located on the compressor. On most models it was cooled by a fan located on the motor. It had a flooded cooling unit, porcelain finished, and used sulphur dioxide as the refrigerant. The cooling coil was equipped with servicing valves built into the header. These valves were capped to prevent corrosion of the valve stem. An external packing nut was used.

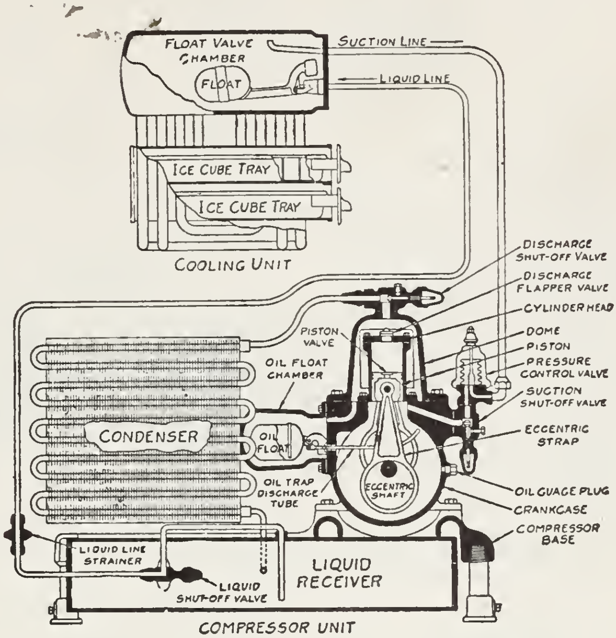
The base or frame for the condensing unit was also the liquid receiver. The low side float systems used a larger liquid receiver in order to store all the liquid refrigerant from the cooling coil during service operations.

Another unique system which used methyl chloride as the refrigerant and had a conventional cycle is illustrated in Fig. 10-5.

One unique feature of the system is the oil trap built into the compressor to prevent the oil pumped out of the compressor from going over into the other parts of the system. This is accomplished by providing a dome-shaped receiver over the cylinder which receives the discharge from the compressor. An inverted cylindrical baffle inside the dome and surrounding the cylinder collects the oil pumped by the compressor. The oil then flows to a float-controlled oil reservoir at the left of the compressor crankcase. As the oil level rises, the float will be lifted and

a needle valve opens allowing the oil to flow back into the crankcase of the compressor. The oil flows into the crankcase due to the pressure difference between the two chambers, as high pressure is on the surface of the oil in the oil reservoir and low side pressure exists in the crankcase. This device is used because oil dissolves readily in methyl chloride and is heavier than the liquid refrigerant. If adequate provision is not made to separate the oil from the refrigerant, it would tend to collect below the refrigerant in the cooling coil and interfere with its operation. In studying the illustration it should be noted that the low side float in the cooling coil is counter-balanced because of the low specific gravity of the refrigerant (methyl chloride).

A low side suction pressure control, built in the end of the suction service valve, prohibits excessive low side pressure from accumulating in the crankcase, which would make it difficult for the compressor to start. The service valves used in the system are of the capped type to prevent corrosion of the valve stems.

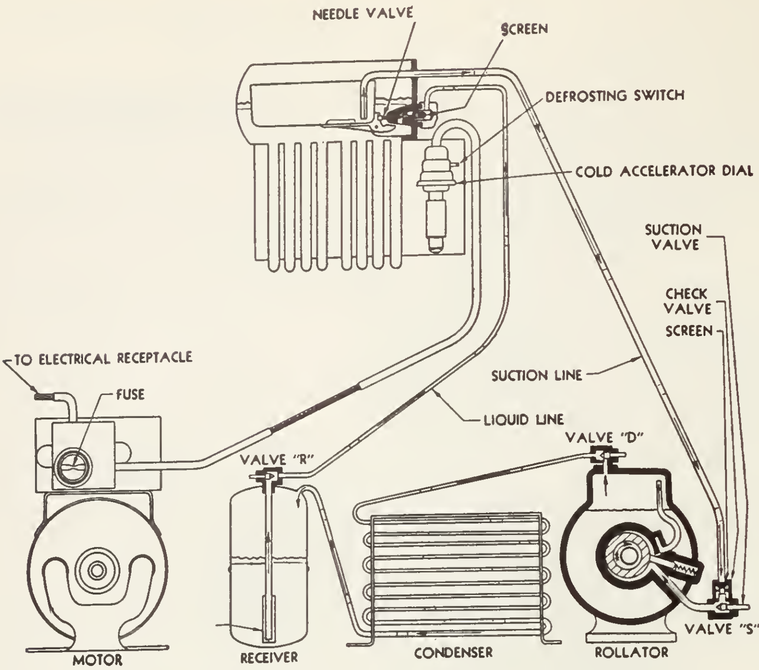


10-5. A conventional low side float system using a reciprocating compressor. Note the pressure control valve on the low side and the oil trap on the high pressure side.

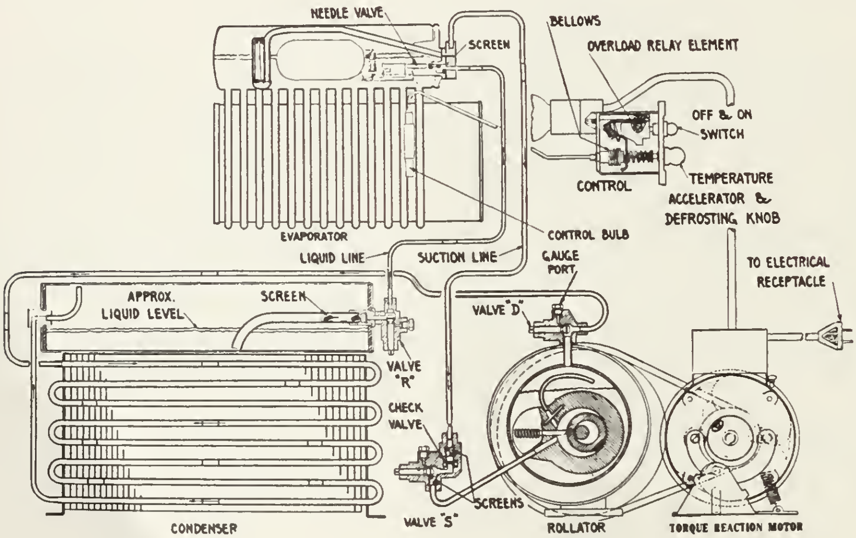
10-9. LOW-SIDE FLOAT WITH ROTARY COMPRESSOR

A low side float system which had several unique features was produced in the 30's. Fig. 10-6 illustrates the mechanism and shows the following different devices:

Instead of the reciprocating compressor, this unit used a rotary mechanism. It consists of an eccentric crankshaft, enclosed in a circular housing with a free sleeve mounted on the eccentric of the crankshaft. It has two ports located in the housing and separated by a movable blade which is always in contact with the sleeve. The duty of this compressor is identical to that of the reciprocating type and it performs as follows: Rotating of the crankshaft creates a space on the suction side of the blade allowing gas to enter



10-6. A low side float system using a rotary compressor.



• 10-7. A low side float system. A wick placed in the suction line opening inside the float chamber aids in removing oil from the surface of the liquid refrigerant.

this space through the suction port. As it continues to roll around, it pushes this quantity of gas around the chamber, at the same time compressing it until the gas is pushed around to the other side of the blade. As the pressure builds up it is discharged out of the exhaust port located on this side of the blade.

The high pressure gases are fed to a storage chamber in the top of the compressor which is also used as the oil reservoir. The crankshaft opening to the belt wheel is located in the high pressure side and therefore the compressor seal is a high pressure seal. This differs materially from the reciprocating compressor design.

This refrigerator is equipped with service valves placed in the conventional manner and the cooling unit is the low side float type with an open pan float.

This unit had a check valve in the suction line so that when the compressor was not running, the oil in the compressor and the high side pressure could not back up into the cooling unit.

A newer model operated much the same as illustrated in Fig. 10-7. The new Rollator compressor has a housing surrounding the compressor which serves as an oil reservoir.

The float in the flooded cooling coil is ball type instead of the open pan type. A wick arrangement in the float chamber was attached to the open end of the suction line and provided a means of removing oil from the surface of the refrigerant. The liquid receiver was mounted above the condenser and a torque reaction type motor was used which automatically kept the belt tight. Note the location of the check valve and the screens on each side of the check valve.

Another low side float system which used a cabinet top mounted condensing unit was so designed that it need not use a crankshaft seal. This mechanism was sealed under a dome and was unusual in that it had two motors, one was connected to a horizontal, single cylinder, reciprocating type compressor of hermetic design. The other small electric motor was used to provide forced draft over the air-cooled condensing coils, Fig. 10-8. The whole unit was compactly designed with the condenser located below and around the compressor. The whole unit was placed on top of the cabinet, at one side, or underneath as seemed fit. The refrigerant was methyl chloride and the apparatus was equipped with a filter or dehydrator to remove moisture. It had an oil trap also to keep away from the cooling unit which is the open-pan float type. The apparatus is equipped with service valves and is completely serviceable although it is of the sealed design.

Note that the intake valve is a port, and that an eccentric crankshaft and connecting rod are used. A ''Mercoid'' switch, centrifugally operated, is used to disconnect the starting winding.

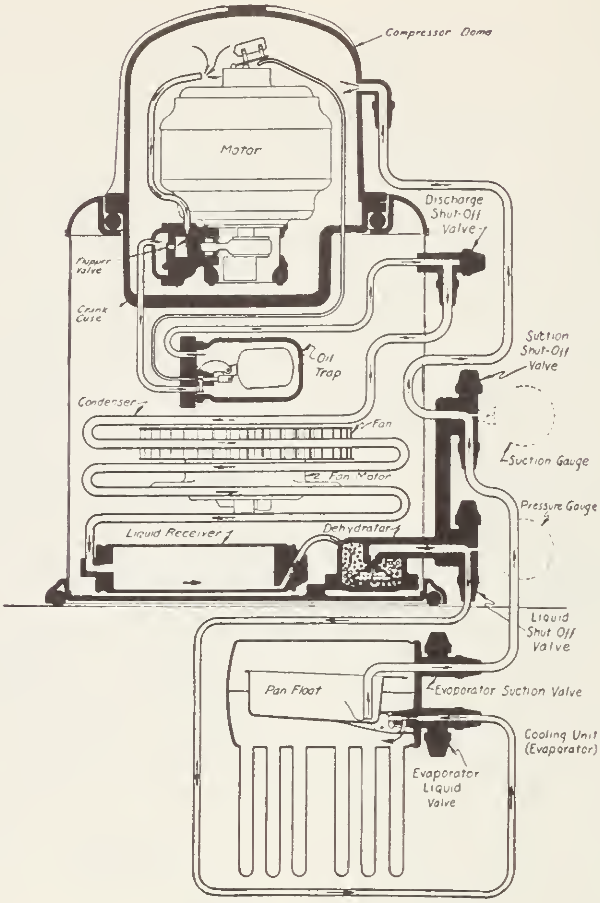
10-10. HIGH SIDE FLOAT SYSTEMS

The high side float system was used as early as 1925 when Servel used the high side float on their units. This control was very popular in the 30's and was considered the best system at that time. The simplicity of the capillary tube system however soon made this the most popular.

These high side floats were located in a variety of places: Some were in the bottom of the cabinet on the base unit, others were mounted on top of the cabinet (top mounted units): Still others were mounted on the back of the refrigerator cabinet, partly buried in the refrigerator insulation.

There have been three arrangements of the high side float systems:

1. High side float.



10-8. A low side float system using a hermetic reciprocating compressor. Note the dehydrator in the liquid line also the open pan type float.

2. High side float with a weight check valve.
3. High side float with a capillary tube.

The latter two systems enabled the manufacturers to place the high side float near the condenser on the base of the unit and to place this assembly in the base of the cabinet.

One example of the unit that used a high side float only was a top mounted unit.

This unit used semi-hermetic design with a belt-driven rotary compressor. Fig. 10-9. The high side float shown, was located beside the condenser. The high side float had a purging and service connection on top. The compressor was a one blade rotary type.

Note that the base of the unit forms the top of the cabinet; therefore, it is insulated.

10-11. HIGH SIDE FLOAT WITH A WEIGHT CHECK VALVE

A system made in 1935 used a high side float and a weight check valve (a pressure differential valve) Fig. 10-10.

This unit used a twin cylinder compressor with both the suction service

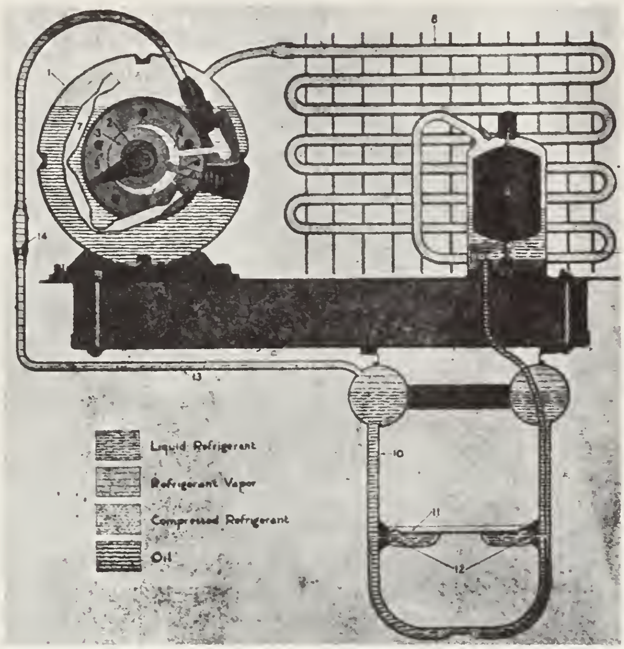
valve and the discharge service valve built into the compressor head. (G) A high side float refrigerant control (C) located on the compressor base, was used with an auxiliary weight check valve (L). The purpose of this weight check valve was to maintain a pressure in the liquid line of 25 pounds per square inch above that in the cooling unit, preventing the refrigerant from evaporating and freezing before it gets into the cooling unit.

The condenser (B) was a stamped unit. The liquid line (D) was insulated (K) to keep it from sweating and frosting.

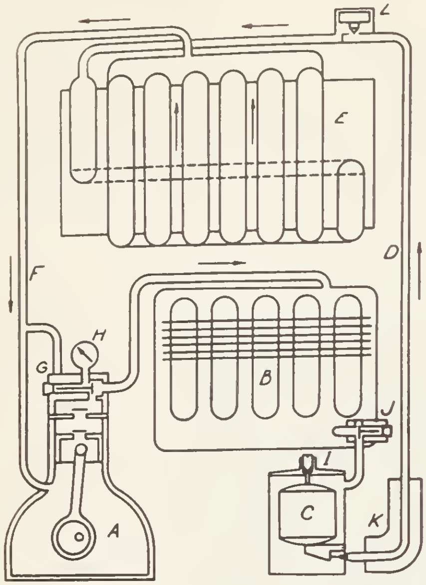
The Leonard refrigerator mechanism was the first to use the high side float with a weight check valve (1931).

From the diagram (Fig. 10-11) may be seen that the refrigerator was equipped with a float located in the liquid receiver, and a weight valve was used in the base of the cooling unit. It functioned as follows: when enough refrigerant had condensed in the liquid receiver, the float opened and allowed the liquid refrigerant to flow up to the cooling unit, but it could not flow into the cooling unit until there was a difference in pressure of 25 pounds between the liquid line pressure and the low pressure side. This difference in pressure raised the meter valve or weight valve located in the rear of the cooling unit and allowed the refrigerant to flow into the low pressure side. This system may be said to have had three pressures: the low pressure and the high pressure as usual and an intermediate pressure located in the liquid line between the weight valve and the float valve in the receiver. This intermediate pressure was never more than 25 pounds over the low side pressure. This system used sulphur dioxide as the refrigerant.

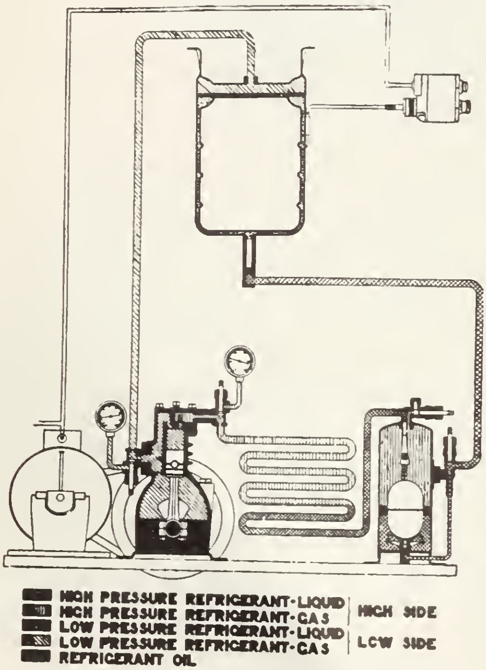
The compressor design may be followed from the cycle diagrammatic



10-9. A high side float system using a rotary compressor.



10-10. A high side float with a weight check valve (a weight loaded pressure differential valve).



10-11. A high side float located in liquid receiver.

sketch and it will be noted that it had an unusual feature in that the location of the intake valve of the compressor was in the cylinder head and not in the head of the piston. Note the extra service purging valve located in the top of the liquid receiver. This valve was used for purging non-condensable gases from the float chamber. The cooling unit style of construction is called the shell type.

10-12. HIGH SIDE FLOAT WITH A CAPILLARY TUBE

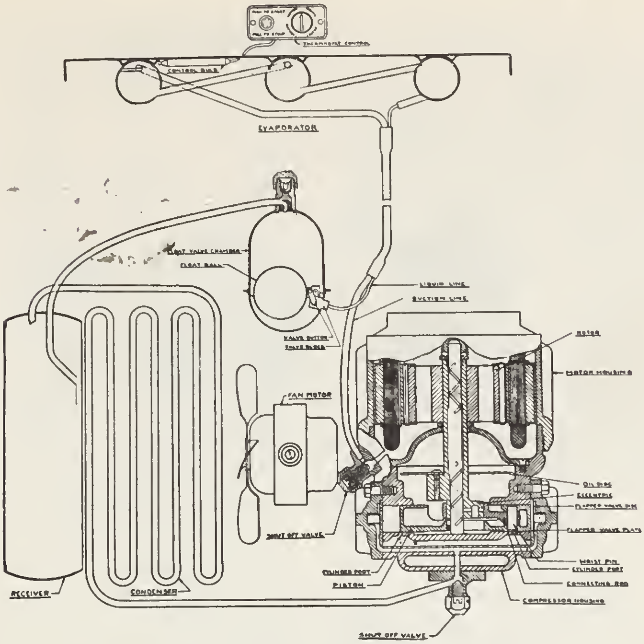
Another system that used the high side float and capillary tube is shown in Fig. 10-12. This unit was produced in 1933-35. The motor was placed inside the sealed compressor housing which eliminated the crankshaft seal. A high side float refrigerant control with a capillary tube feed to the cooling coil was used.

The valve on this high side float control consisted of a sliding button rather than a needle valve. The unit was located in the base of the refrigerator. The unit had shut-off valves in the liquid and suction lines only, to permit replacing of the condensing unit. The cooling unit was unique in refrigeration, for it was the shelf type placed across the top of the box. The unit used a 1/5 H.P. motor.

Note that the compressor was a two cylinder horizontal opposed type with both pistons made of one piece of metal. It used only one connecting rod. The cylinder heads were bolted to the cylinder and the unit used intake ports instead of valves.

Another unit with many innovations (the Grunow) appeared on the market in 1933.

Carrene (methylene chloride) was the refrigerant used. Carrene is one of the most unusual refrigerants in that it operates under a vacuum both on the high and low pressure sides. Normal-



10-12. A high side float with a capillary tube.

ly, the pressures are 27 in. of vacuum on the low side and 5 in. vacuum on the high pressure side.

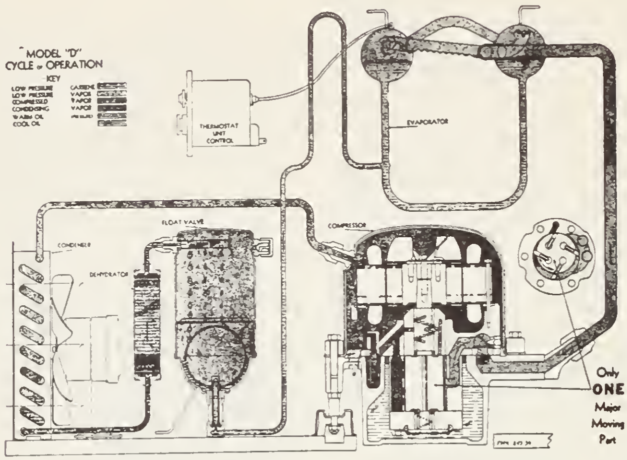
The unit consists of a rotary vane type compressor directly driven by the motor. Both the motor and the compressor are mounted vertically under a common dome, Fig. 10-13. The unit used a high side float mounted beside the condenser. The condenser was cooled by a separate fan and motor. A dehydrator is permanently mounted between the high side float and the condenser. The high side float is constructed in such a way that the chamber can hold all of the refrigerant in the system. All of the condensing units were mounted in the base of the cabinet.

A capillary tube carried the refrigerant from the high side float to the cooling coil. The suction line was 5/8 in. O.D. Two service valve attachments were provided, one on the high side float and one on the cooling coil.

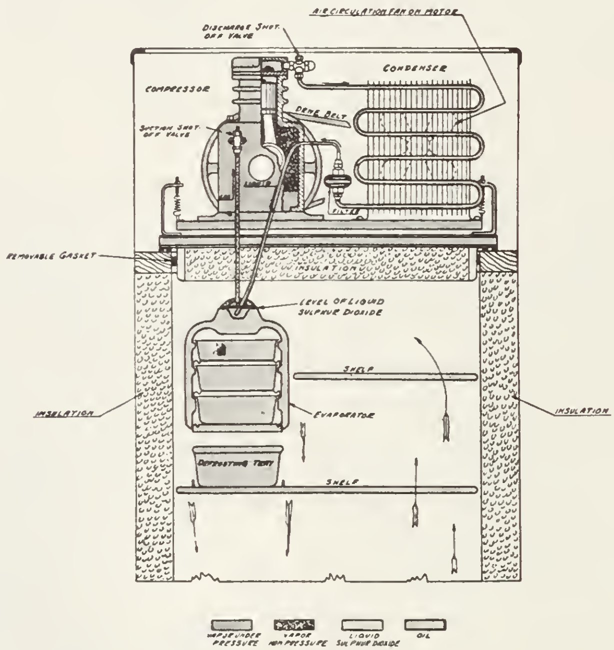
10-13. CAPILLARY TUBE SYSTEMS

The refrigerating systems that used the capillary tube refrigerant control originated in 1928. The Rice refrigerator system used the original capillary tube system. Starting about 1934 some of the Frigidaire systems used a restrictor. This unit restricted the refrigerant flow by making it pass through a small helical passage.

In Fig. 10-14 is shown condensing and cooling units so designed that they may be removed in one piece from the cabinet. The cycle and operation may be easily followed. The unit used sulphur dioxide as the refrigerant and the refrigerant control was of the capillary tube type construction. This capillary tube was mounted between the filter and the cooling unit. Note that it did not have a liquid receiver. A liquid receiver was not necessary due to the capillary tube refrigerant control. Also, the quantity of refrigerant put in



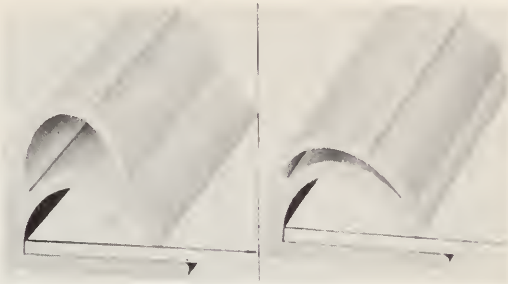
10-13. A high side float with a capillary tube (Grunow).



10-14. A capillary tube with a reciprocating compressor.

the system was carefully measured. The lower tubes of the condenser serve to store sufficient quantities of liquid refrigerant. A different type service valve was located between the condenser line and the cylinder head. This service valve threaded into the cylinder head and when the compressor was to be removed the valve was turned all the way in and the cylinder head was then unbolted from the compressor.

The intake valve, a spring steel disk, was located in the piston. An eccentric was used instead of the usual crankshaft, and it was fastened to the compressor shaft by a bolt and key in addition to the typical Woodruff key design. Lubrication was by oil splash, and wells were used to feed the oil to the bearings and seal. The crankshaft seal was of the diaphragm type backed by a rubber washer with the seal pressure exerted type backed by a rubber washer with the seal pressure exerted by a spring at the opposite end of the crankshaft. The complete condensing unit was mounted on springs to minimize vibration. The cylinder had integrally cast air-cooled fins to reduce the temperature of the compressor.



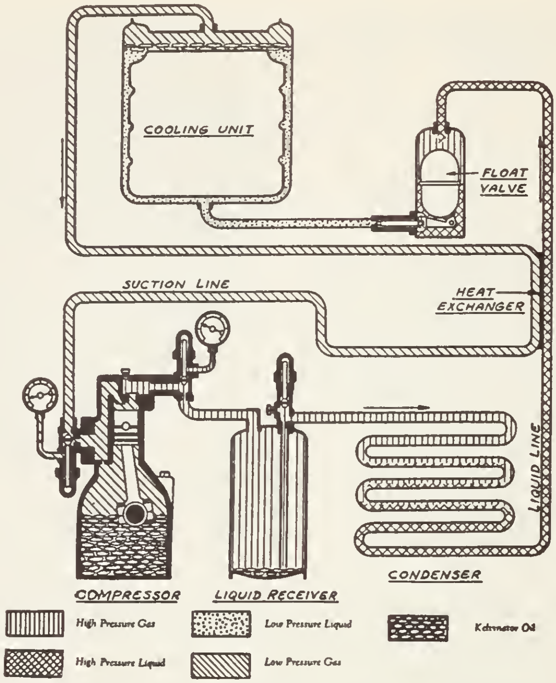
10-15. A door gasket developed for magnetically latched doors and safety latch doors. It seals tightly with only a four-pound force. (Jarrow Products Co.)

Most domestic refrigerators converted over to the capillary tube system in the 1940's. A legal decision about 1940 enabled all the companies to use the capillary tube refrigerant control without paying royalties. This control became the only one used by the companies from that date.

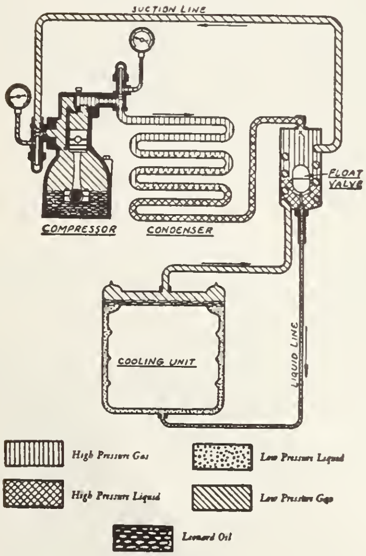
A new type gasket specially developed for doors that are feather light to close is shown in Fig. 10-15. This rubber gasket is used on safety-type spring and magnetic refrigerator and freezer doors. Note how the gasket clamps under the door liner and how the open tube design enables a sealing action with very slight pressure.

10-14. REVIEW QUESTIONS

1. How is the condenser cooling fan usually driven?
2. Why is a weight valve used in connection with some high side float control mechanisms?
3. Why has the low side float been discontinued on domestic refrigerators?
4. Do all condensers have fans to circulate the air?
5. Have pressure motor controls ever been used on domestic systems?
6. Have thermostatic expansion valves ever been used on domestic systems?
7. What refrigerants have been used with the low side float systems?
8. When was the first capillary tube used?
9. Have all condensing units been located in the base of the cabinet?
10. Why was a capillary tube sometimes used with a high side float?



The 1936 Kelvinator refrigerating cycle. Note the location of the liquid receiver. It is used for emergency and shipping storage only



The 1936 Leonard refrigerating cycle. Note the heat exchanger built into the high side float chamber

10-16. Several refrigerating cycles that have been used during the past several decades.

10-15. UNUSUAL MECHANISMS

A number of interesting refrigerating mechanisms have been developed, manufactured, and used through the past several decades. Figure 10-16 illustrates two of the unusual units that proved practical, but eventually gave way to the hermetic units now in almost universal use.

Chapter 11

SERVICING CONVENTIONAL SYSTEMS

A competent service man must be well acquainted with the fundamentals of refrigeration and must be adept in the proper use of tools before he is qualified to work on a conventional refrigerating mechanism. A good knowledge of fundamental refrigeration is needed to dismantle and assemble the mechanism and to locate troubles. A knowledge of the handling of tools is necessary in order to lap valves properly, to fit tubing, and to assemble the parts in the proper manner.

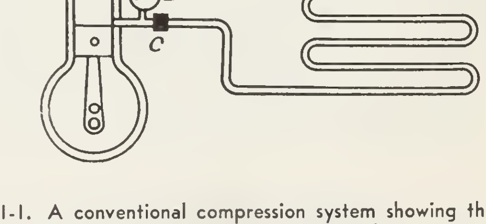
The ability to locate trouble and determine its cause is a main qualification of a competent refrigerator service man. Practically any careful mechanic can overhaul a refrigeration mechanism once it is taken apart, but it requires a specially trained mechanic to dismantle and assemble a refrigerator, and it also requires special training to diagnose troubles and make repairs on the mechanism. It is very important to read and study this complete chapter before attempting any repairing.

11-1. SERVICING CONVENTIONAL REFRIGERATOR UNITS

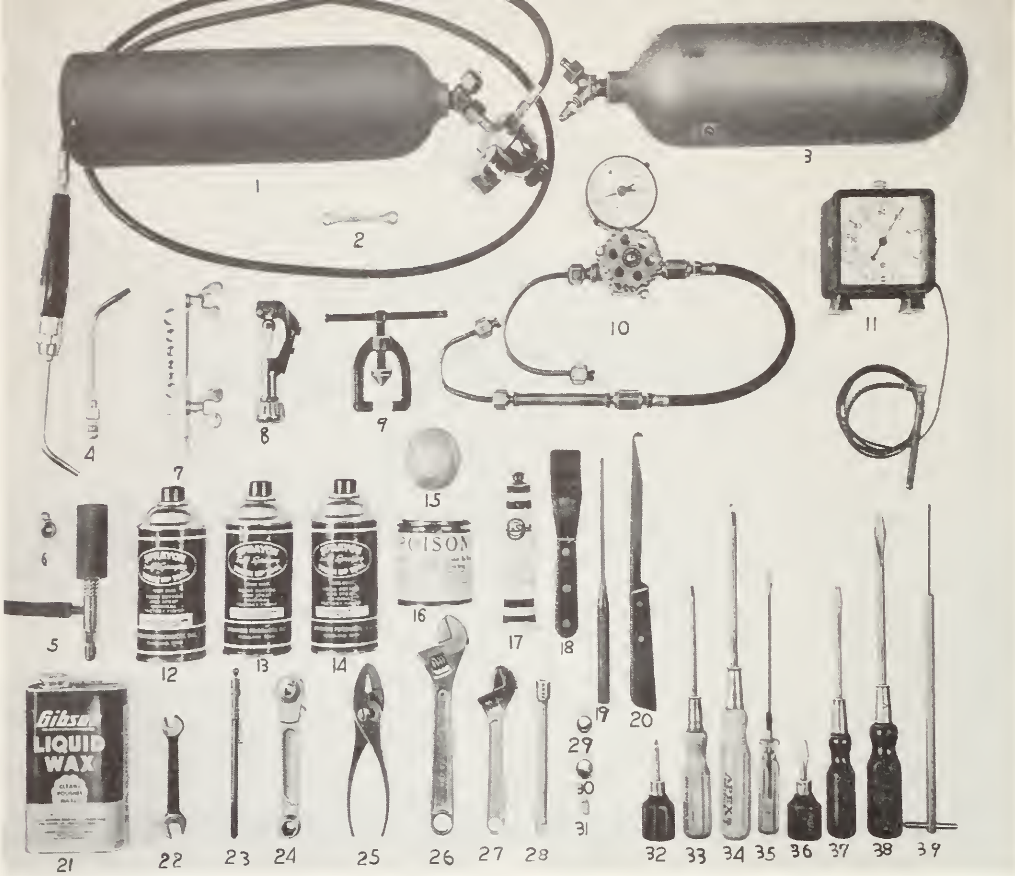
As all of the reciprocating compressor type refrigerators are much the same, general instructions will apply to nearly all of them. Although all of the domestic refrigerating units being made today are hermetic, there are still many conventional units in use.

11-2. DISMANTLING

Generally speaking, to remove any part of the mechanism it is first necessary to remove the refrigerant from the mechanism. This is done by installing gauges in the system, the proper manipulation of the service valves, and operation of the compressor. See Fig. 11-1. The removal of any part is usually accomplished by drawing a low pressure or vacuum on that part to be dismantled in order to evaporate the refrigerant from it, and then by equalizing the pressure to 0 pounds



11-1. A conventional compression system showing the location of the gauges and the servicing valves. A. High pressure gauge; B. Compound gauge; C. Suction service valve; D. Discharge service valve; E. Liquid receiver service valve; F. Expansion valve.



11-2. A typical set of tools needed for servicing operations.
(Gibson Refrigerator Co.)

per square inch gauge. The vacuum, of course, removes the refrigerant and the equalizing or balancing of the pressure prevents a rush of air into the mechanism, when the system is opened. This last step is very important. The process is performed by closing the inlet service valve to the part to be removed, running the compressor until the gauge shows a 0 psig to a 28 in. vacuum, and then after opening the inlet service valve until the gauge reads zero, closing the inlet service valve to that part, cleaning the joints and then removing the parts.

11-3. TOOLS

The service man should be equipped with an adequate tool kit. Tools required include: valve wrenches, gauges, storage cylinders for the refrigerant, wrenches, and a torch, Fig. 11-2. The service man is helpless without a proper array of tools. See Chapter 2 for more detailed description of the tools.

A service man's complete tool kit will comprise the following:

1 Refrigeration ratchet wrench with 3/16, 7/32 and 1/4 in. square openings

1 1/4 in. square to 1/4 in. square ratchet wrench adapter

1 1/4 in. square to 3/16 in. square ratchet wrench adapter

1 1/4 in. square to 7/32 in. square ratchet wrench adapter

1 3/16 in. internal packing nut adapter

1 1/4 in. internal packing nut adapter

1 Set of bending springs for 1/4, 3/8, and 1/2 in. O.D. tubing

1 Tube cutter

1 Flaring outfit to use on 3/16, 1/4, 5/16, 3/8, 7/16, 1/2 in. O.D. tubing

1 gauge manifold

1 Compound gauge 30 in. Hg--0--150 psig

1 High pressure gauge 0--300 psig

1 8 in. adjustable open end wrench with maximum jaw opening of 1 in.

1 1/2 in. end wrench 15 degrees

1 3/4 in. end wrench 15 degrees

1 7/8 in. end wrench 15 degrees

1 1 in. end wrench 15 degrees

1 1/2 in. box wrench

1 1/2 in. "T" socket wrench

1 3 in. screwdriver

1 6 in. screwdriver

1 8 in. screwdriver

1 Blow torch

1 Bottle of 28 per cent aqua ammonia

1 set of Allen set screw wrenches

1 5 lb. cylinder of Freon-12

1 5 lb. cylinder of sulphur dioxide

1 3 lb. cylinder of methyl chloride

1 Set of sockets with from 7/16 in. to 1 in. openings (12 point preferred.)

1 T-handle wrench for the above sockets.

1 Survil handle wrench for the above sockets

1 Torque handle wrench for the above sockets

1 Speed handle wrench for the above sockets

1 Pinch-off tool (For extreme emergencies only)

1 Thermometer - 20F. to 0 to 120 F.

1 Set of fittings, i.e. nuts, elbows, unions, half unions, "tee," caps, plugs, etc.

1 Purging line ($\frac{1}{4}$ in. x 15 ft.) equipped with a hand shut-off needle valve and a check valve

1 Brush--round with filter bristles

1 Cleaning cloth

1 2 lb. can of lye for sulphur dioxide systems

1 Gasket scraper (ground file)

1 Glass lapping block

1 Can of refrigerant oil (spout type)

1 Can of refrigerant oil, 300 viscosity

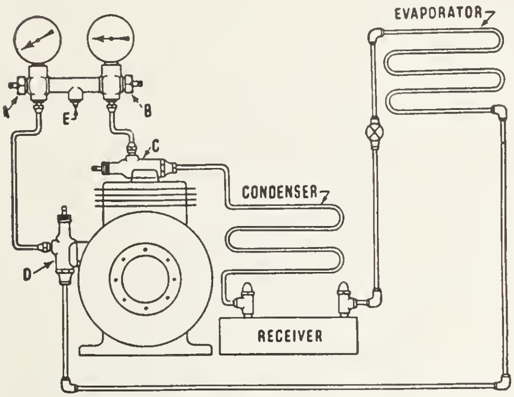
1 Can of refrigerant oil, 150 viscosity

11-4. INSTALLING GAUGES

Before attempting any trouble shooting or service work on any unit, pres-

sure gauges should be installed and the cooling unit temperature should be taken.

A very careful procedure must be followed when mounting the gauges on a refrigerating system to insure a clean system and a long life for the



11-3. A service gauge manifold. A. A compound gauge manifold valve; B. A high pressure gauge manifold valve; C. Compressor discharge service valve; D. Compressor suction service valve; E. Purging and charging manifold connections.
(Mueller Brass Co.)

gauges. These gauges are either screwed directly into the service valves, by means of a 1/8 in. pipe or a 1/4 in. pipe connection, or by short runs of 1/4 in. tubing with which the appropriate fittings are used. A gauge manifold may also be used. Its installation is described in Paragraph 11-5. The service valves on refrigerators in service are usually turned all the way out ready to receive the gauge in the gauge opening; however, the service man should always check to make sure the gauge opening is closed off before removing the gauge opening plug.

The following is an approved procedure for installing gauges: First, loosen the packing nut one complete turn and turn the valve stem all the way out. Clean the exterior of the service valve with a brush, and a cleaning cloth and remove the gauge plug. Mount the gauge into the gauge opening, being careful not to twist on the gauge body; that is, do not tighten the gauge into the fitting by twisting with the hand, but rather use the proper size wrench.

Now turn the valve stem in, using the fixed end of the service valve wrench, and turn it in only a very small distance (1/16 to 1/8 turn). This "cracking" is to prevent the rupturing of the gauge mechanism in case there is an excessive pressure released into the gauge Bourdon tube. Shut off the valve in case the pressure builds up too rapidly. Stop the machine, if necessary, to build up a positive pressure of from 5 to 10 psig and then test for leaks. The gauge is now in position for use.

11-5. INSTALLING A GAUGE MANIFOLD

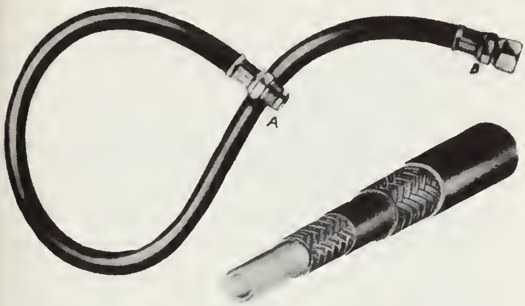
A service device which has been of considerable aid to servicemen for several years is a service gauge and testing manifold. Fig. 11-3. Its use enables one to charge and discharge a system, check the pressures, add oil to a system, add liquid dryers to a system, by-pass the compressor, unload the gauge lines of high pressure liquid and gas and perform many other operations without replacing gauges and operating inaccessible service connections.

A typical manifold provides two gauge openings, three line connections and two shut-off valves that separate the gauge openings from the center line connection. This manifold enables the serviceman to connect his gauges to the system and then allows him to do practically all service and adjustment operations without removing the gauges even temporarily.

The manifold usually has 1/4 in. square drive valve stems although some are equipped with hand wheels. The three line attachment fittings are usual-

ly 1/4 in. MF. The manifold is connected to the SSV (D) and the DSV (C) by means of 1/4 in. dia. copper tubing or by means of flexible lines. Fig. 11-4. Because most of the service valves have 1/8 in. FP gauge openings two 1/8 in. MP x 1/4 in. MF half unions are installed in the service valves. Be sure the service valve stems are turned all the way out and that the valve is cleaned externally before removing the pipe line plugs and installing the half unions.

After the half unions are installed in the gauge openings, the lines from the manifold are attached to these fittings. The line attached to the SSV(D) should be left one to two turns loose



11-4. A flexible charging line. Note the wall construction. A. External flare connection; B. Internal flare connection.
(Resistoflex Corp.)

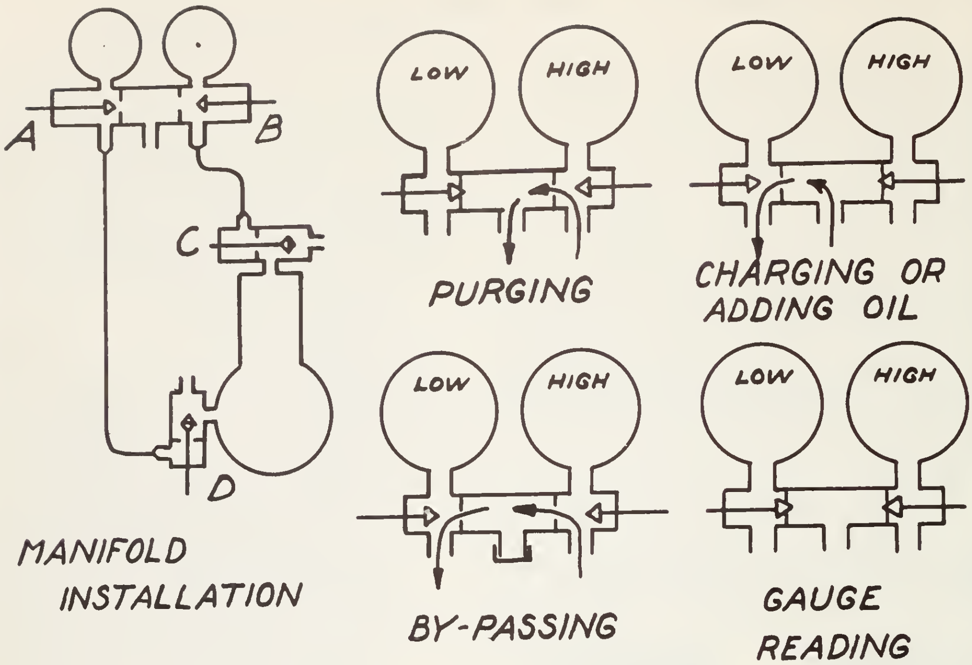
while the line to the DSV should be tightened. Then open both the manifold valves (A and B) 1/4 to 1/2 turns and cap the middle opening (E). Now turn the DSV (C) stem in 1/8 to 1/4 turn momentarily. A surge of high pressure refrigerant will then rush through the lines and the manifold and purge to the atmosphere at the loose connection at the SSV(D). The connection at the SSV(D) may now be tightened. This purging is very necessary to remove all the air and moisture from the manifold and also the lines, Fig. 11-5.

Carefully test for leaks while the manifold and its lines are under high pressure. CORRECT ANY LEAK IMMEDIATELY.

After the testing manifold has been installed as indicated the various service and testing operations may be performed as follows:

1. Observe operating pressures by:
   Closing valve A
   Closing valve B
   Cracking open back seat of valve C
   Cracking open back seat of valve D
2. Charge refrigerant through compressor by:
   Connecting refrigerant drum to E
   Opening valve A
   Closing valve B
   Cracking open back seat of valve C
   Closing front seat of valve D
3. Purge receiver by:
   Closing valve A
   Opening valve B
   Back seating then crack open valve C
4. Charge liquid into high side by:
   Connecting refrigerant drum to E
   Closing valve A
   Opening valve B
   Mid positioning valve C
5. Build up pressure in low side for control setting or to test for leaks by:
   Sealing E with seal cap
   Opening valve A
   Opening valve B
   Back seating then crack open valve C
   Mid positioning valve D
6. Charge oil through the compressor by:
   Connecting oil supply to E
   Opening valve A
   Closing valve B
   Turning valve C all the way out
   Turning valve D all the way in

After completing the service operations, the manifold is removed from the system in a manner that prevents a loss



11-5. The installation and various uses of a gauge manifold.

of refrigerant, or admittance of air. Turn the DSV (C) all the way out, then open both the manifold valves 1/4 to 1/2 turn. This arrangement will remove all the high pressure refrigerant from the line and the high pressure gauge. Now turn the SSV(D) stem all the way out and turn the manifold valve stem all the way in. Remove the lines from the service valve, remove the half unions from the service valves and install the service valve gauge opening plugs and tighten them. Immediately plug the lines and all other openings on the manifold to keep out dirt, moisture and air.

11-6. REMOVING A GAUGE

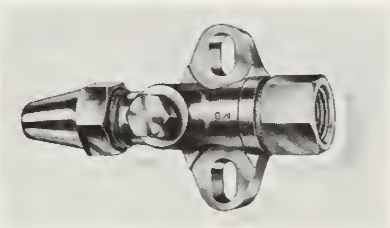
Loosen the packing nut one turn and turn the valve stem all the way out. Remove the gauge (using a wrench), fill the gauge opening with refrigerant oil, and then install the plug. After the plug is tightened firmly into its seat, turn the valve stem back in about 1/16 of a turn; then tighten the packing nut. The purpose of putting the oil into the gauge opening is to have it serve as a lubricant to the valve stem and its packing. The purpose of turning the valve stem back in 1/16th of a turn is to prevent the valve from "freezing" against its seat. Such a condition occasionally leads to broken valve stems. Never tighten a cold gauge plug into a hot service valve. This results in a freezing of that plug into its seat and it probably will be very difficult to remove. When using the service valve wrench on these valves, never use a jerky motion. Always apply the turning force gradually. Adjustable end wrenches or fixed end wrenches are not recommended for service valve stems. Only the special socket wrenches, sometimes called keys, are to be used.

If the gauge plug is "frozen" in the service valve it can be loosened easily by first heating the outside of the service valve body with flame from a torch. This heating will cause the body to expand and will weaken the body thread grip on the plug. The wrench can then be used to loosen the valve stem.

11-7. CARE OF SERVICE VALVES

In all of the refrigerators equipped with service valves, the valves must be leak-proof to obtain a leak-proof joint where the valve stem goes into the valve. Various packings are used. These packings differ with different valve designs and when replacing them one must be sure the proper packing is used.

The packing is usually made of asbestos, lead, and graphite. A replacement service valve is shown in Fig. 11-6. It has a slotted flange that enables one to fit this valve to a great variety of compressor flange sizes.



11-6. A compressor service valve with slotted flange holes and a protective cap over the valve stem. (Mueller Brass Co.)

11-8. PREPARING A REFRIGERATOR FOR SERVICE WORK

It is very important to prevent any damage or excessive disorder when working on any refrigerator. The refrigerator must be protected from damage and dirt. The floor and walk must be kept free of damage and dirt. Always remove any articles that are inside the refrigerator or at least put them to one side and cover them with paper or cloth. Spread papers, or preferably a tarpaulin, around and under the refrigerator, especially if the work is to be done in a home. One must be very careful of all finished surfaces. Porcelain is very brittle and any chipping or cracking of it may necessitate replacing a complete panel. Enamel finishes should not be smeared with oil or grease. Some servicemen fasten newspapers over surfaces they wish to protect and fasten these papers with masking tape or Scotch tape.

11-9. REMOVING ANY PART OF THE SYSTEM

The general steps to be followed when removing any part of any system are as follows:

1. Remove all the refrigerant from the part to be opened.
2. Balance the pressures in the parts just evacuated.
3. Isolate the parts to be opened from the rest of the system.
4. Clean and dry the joints to be broken.
5. All refrigerant openings should be immediately plugged as soon as they are opened.

When servicing a refrigerating mechanism, one must always keep in mind that the internal part of the machine must be kept as chemically clean as possible. Moisture causes acids, sludge and even freezes in the low temperature passages. Dirt (solids) will abrade the control valves, abrade the compressor valves and seats, and clog the screens.

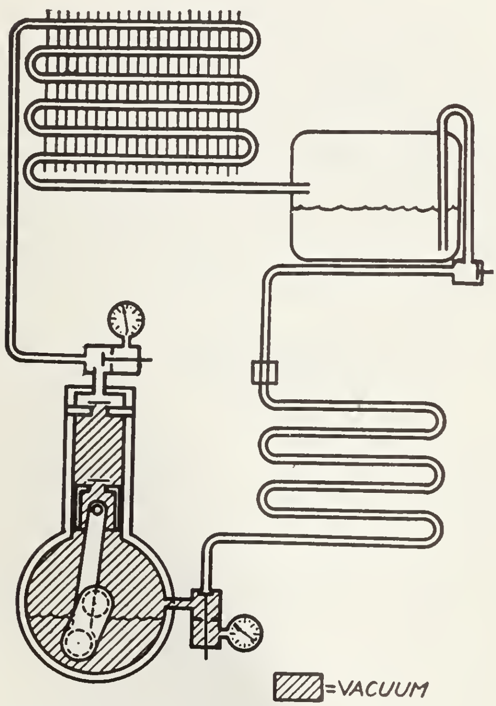
11-10. REMOVING THE COMPRESSOR

Install the gauges, or the manifold; test for leaks very carefully. See Paragraphs 11-37 for leak tests. In order to test for leaks, the pressure must be at least 5 to 15 pounds.

Turn the suction service valve all the way in (closing off the suction line), Fig. 11-7. Start the compressor, but let it run for only a moment in order to eliminate oil pumping, for the oil in the crankcase will bubble vigorously due to the refrigerant coming out. Pumping of

oil is indicated by a pounding noise in the compressor and usually occurs between 10 in. and 12 in. vacuum. After starting and stopping the unit two or three times, it may finally be run continuously. Keep the unit running for a few minutes after a constant vacuum is reached on the suction gauge. If a vacuum cannot be obtained, it means that the compressor is inefficient or that the suction service valve is leaking. Stop the compressor and notice if the gauge creeps. If it does, this signifies that the exhaust valve in the compressor is leaking, that the suction service valve is leaking, or that the crankshaft seal is leaking. In this case the prevention of gas escaping or of air getting into the system will be difficult. These leaks will necessitate a special service operation to rid the system of air.

If the gauge does not creep, crack the suction service valve until the compound gauge reads zero or 1 pound pressure (equalizing the pressures). Then turn the discharge service valve stem all the way in, and unbolt the suction service and discharge service valves from the compressor (do not remove the lines from the valve). The joints should be cleaned before opening. See Fig. 11-7. Immediately plug all the openings through which refrigerant flows using dry rubber, cork stoppers or tape. Disconnect the compressor base bolts that hold the compressor to the base, remove the belt, and the compressor is ready for an overhaul. The oil should be drained immediately. Do not use the old oil again, especially if it shows discoloration. To keep the crankshaft seal from being abused, never rest the weight on the flywheel. Always set the compressor on a block in such a way that the flywheel hangs free, or remove the flywheel.

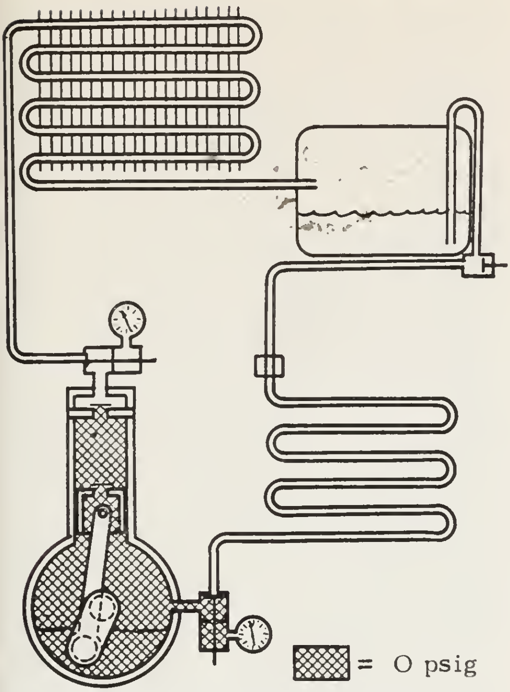


11-7. An illustration showing the suction service valve stem turned all the way in and the compressor evacuated.

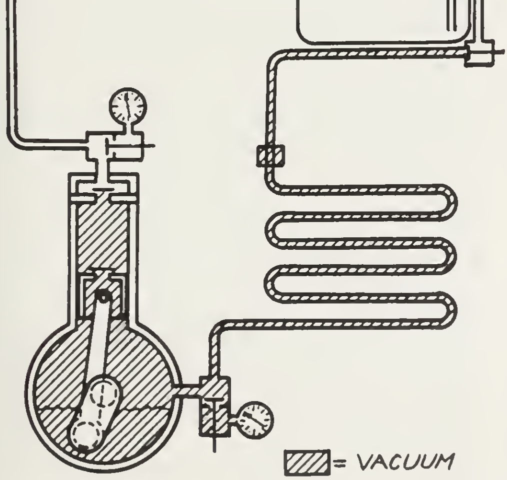
11-11. REMOVING THE COOLING UNIT (DRY SYSTEM)

Install the compound gauge or the manifold and test for leaks. Start the compressor and close the LRSV, Fig. 11-9. Run the compressor until a constant vacuum has been produced and until the cooling unit is warm. To speed up this operation heat the cooling unit carefully with a torch or hot water. Never allow it to get more than warm to the hand. After stopping the motor, open the LRSV a very little until the compound gauge reads zero (equalizing the pressure); then turn the suction line service valve all the way in, closing the suction line. If the system normally operates on a vacuum, one may obtain a balanced pressure (atmosphere) in the cooling unit by either warming the unit, or by bypassing high pressure back through the gauge manifold.

Clean and dry the suction line where it is connected to the cooling unit and



11-8. An illustration showing the two compressor service valves turned all the way in and the compressor crankcase pressure balanced and ready for removal from the system.



11-9. An illustration showing the liquid receiver service valve closed and the compressor evacuating the liquid line and the low pressure side of the system.

also the inlet connection. Then unfasten the suction line from the cooling unit and plug the openings with appropriate fittings.

11-12. REMOVING A HIGH SIDE FLOAT

If the unit has a high side float, the method of removing the refrigerant from the low pressure side may be used in some cases. However, to remove the refrigerant from the condenser and float chamber, the following procedure is recommended: If the float chamber is equipped with a purging valve, connect a line from this valve to the suction service valve of the compressor. Then connect a refrigerant cylinder to the discharge service valve gauge opening and turn the DSV stem all the way in. Purge both of these lines and then start the compressor. As the compressor runs, it will pump the refrigerant out of the condenser and float chamber into the cylinder. A constant vacuum will indicate when all the refrigerant has been removed. The cylinder should be cooled by using cold water or water and ice cubes during this operation to speed up the condensation of the refrigerant in the cylinder. It is not good practice to save this refrigerant unless the cylinder was clean before it was filled, and unless the refrigerant is to be put back into the same unit.

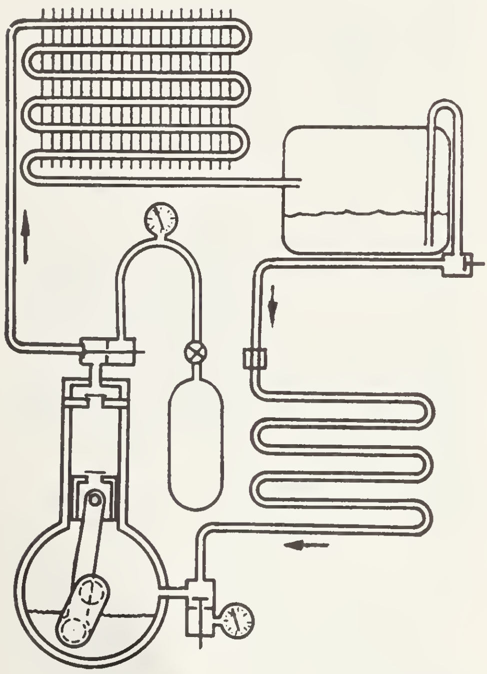
Balance the pressure by "cracking" the discharge service valve, and the float may be removed.

If one wants to keep the refrigerant in the cooling coil, turn the suction service valve stem all the way in. Clean the connections before breaking open any of the joints. A quicker way is to throw away the refrigerant in the float chamber by isolating the float chamber and then purging to the outdoors or neutralize with lye in case of sulphur dioxide.

11-13. REMOVING A LOW SIDE COIL

There are two methods of removing the flooded cooling unit and they depend on whether or not the refrigerant is to be left in the cooling unit.

1. The refrigerant may be left in the cooling unit if the cooling unit is equipped with service valves between the lines and the cooling unit. This method will necessitate leaving both the service valves on the cooling unit; therefore it will apply to all types of valved cooling units. To leave the refrigerant in the cooling unit, proceed as follows: close the liquid receiver service valve and run the compressor for about 1 minute or until the liquid line becomes warm. In the meantime, heat the liquid line slightly with a torch or by rubbing one's hand on it. This action will remove all the liquid refrigerant from the liquid line. Then close the liquid line valve located on the cooling unit. It is best to close this valve when the compound gauge is reading about zero pounds. The liquid line may be disconnected and plugged after the exterior has been carefully cleaned and dried. Turn the cooling unit suction line valve stem all the way in, and balance the pressures in the suction line by manipulating this valve. Clean and dry this connection, remove, and plug the suction line. By carefully bending the suction line and liquid line to prevent the buckling of them, the cooling unit may be readily unbolted and removed from the cabinet. Many cooling unit mounting devices become corroded and are difficult to remove. Heat them carefully (do not heat the porcelain) or use penetrating oil.



11-10. An illustration of a method discharging a system.

2. If the cooling unit is not equipped with service valves, or if the refrigerant is to be withdrawn from the cooling unit, use the following prodedure: Install a compound gauge in the suction service valve and test for leaks. Start the compressor and shut off the liquid line at the cooling unit if it is provided with bolted valves, or close the liquid receiver service valve if it is not. Continue to evacuate the cooling unit, heating it carefully as suggested to speed up the work until a constant vacuum has been produced. Next stop the compressor and crack the cooling unit valve or the liquid receiver service valve until the pressure has been equalized, that is, until the compound gauge reads zero. Now, turn the suction service valve stem all the way in. After cleaning the connections at the cooling unit, remove them very carefully, and plug all the openings immediately. If the cooling unit is equipped with valves, and the cooling unit liquid line valve has been shut off, this valve must be unbolted from the cooling unit. This means that it will be impossible to seal the cooling unit openings; therefore, the method whereby the liquid receiver

service valve is the valve manipulated, is the best.

11-14. REMOVING THE REFRIGERANT, CONDENSER, RECEIVER TANK

In this case, all the refrigerant must be thrown away or stored in an outside cylinder. Turn the discharge service valve all the way out and attach a line from a storage cylinder, if one is to be used, to the valve. The storage cylinder may be connected to the center opening if a manifold is used. Purge the line leading from the cylinder by sealing the line at the cylinder; then leaving it loose at the discharge service valve, crack the cylinder valve and the escaping gas will force the air out of the line. Seal the line at the discharge service valve, close the discharge line of the compressor by turning the discharge service valve all the way in, test for leaks, and start the compressor. Place the cylinder in a bucket of water in order to keep it as cool as possible. Fig. 11-10. This action will promote the condensation of the refrigerant in the cylinder. Allow the compressor to run with all but the discharge service valve open. Shut the compressor off after a constant vacuum has been maintained for several minutes. When one does this operation the first few times, a high pressure gauge should be connected to the refrigerant cylinder to enable the service man to observe the head pressure. The pressure should not exceed 50 psi over the normal condensing temperature for the particular refrigerant. Excessive head pressures may be avoided by cooling the refrigerant tank with ice, or water, or by running the compressor intermittently. Saving the refrigerant is not recommended in small systems because it might be saturated with dirt and impurities. The cost of 1 or 2 pounds of refrigerant is not excessive. Never allow the system to pump oil as the hydraulic pressures may cause serious damage to the compressor and lines. Never use the refrigerant in any system but the one it was removed from unless the refrigerant is distilled and dried. The operation may be speeded up by applying a torch to the liquid receiver tank and to the cooling coil. Keep the torch away from fuse plugs and soldered joints.

The refrigerant has now all been pumped from the system and is placed in a storage cylinder.

Close the cylinder valve and stop the compressor; then after opening the discharge service valve, crack the cylinder valve until a zero pressure is indicated on the compound gauge. This action returns enough gaseous refrigerant to balance the pressure in the entire system. Before opening it to the air, close the liquid receiver service valve and turn the discharge service valve stem, all the way in and the condenser and receiver may be removed from the mechanism.

The above method is also used for removing the refrigerant. As mentioned before, clean and dry all the connections to be opened and immediately upon removal of any parts, the refrigerant openings should be carefully plugged. Whenever the service man wants to discard the refrigerant, he may either exhaust it to the air or in some cases (sulphur dioxide) discharge it into a neutralizer such as lye.

A good practice to follow when discarding refrigerant is to attach a purging line made of 1/4 in. copper tubing to the discharge service valve gauge opening. This purging line should have a hand needle valve and a check valve mounted in the compressor end. The hand needle valve should be located between the check valve and the purging line.

The purpose of the hand valve is to control the amount of gas purged while

the check valve prevents the backing up of air or moisture into the unit after it has been completely purged. Another common practice for discarding refrigerants is to purge the gas down a sewer. This practice is not recommended due to the corrosive action of some refrigerants. If it is done, the water tap should be opened and the water allowed to flow rapidly in order to wash the refrigerant along.

Because all refrigerants being purged have an oil content the purging should be done into an oil trap. Always purge a refrigerant into a well ventilated space.

11-15. REMOVING AN EXPANSION VALVE

Install the gauges or the gauge manifold and test for leaks. Close the liquid receiver service valve and run the compressor until a constant vacuum is maintained for a few minutes. Equalize the pressure by cracking the liquid receiver service valve. Turn the suction service valve stem all the way in, dry and clean the expansion valve. Then remove the liquid line and unbolt the valve from the cooling unit. Seal the refrigerant openings immediately. This method is similar to removing a flooded cooling unit not equipped with service valves.

11-16. REMOVING A FLOAT VALVE

There are two principal types of float valves. First, the type which is completely removable including the float, the needle, and the refrigerant openings. Second, the cartridge type in which the header is welded to the body, and the needle and seat are built into a cartridge. The float cannot be removed in this latter type which usually uses the open pan type floa+

1. To remove a bolted cooling unit float valve, the same procedure is followed as when removing the cooling unit itself with a few additional precautions. When doing the project, have the new float valve and a new lead gasket handy so the job may be done quickly. Also, tilt the cooling unit back before unbolting the header to prevent the oil from running out. ALWAYS REMOVE FOOD FROM A BOX BEFORE WORKING ON A COOLING UNIT.

2. A cartridge type of needle valve may be replaced using the same method previously explained with the exception that the suction line does not have to be removed. The cartridge needle assembly that screws out of the header is all that needs servicing. In this type of float valve the needle fastens to the float by means of a spring snap. Inserting the cartridge automatically fastens the needle to the float.

11-17. REMOVING A SERVICE VALVE

Occasionally a service valve stem will break or the threads will strip, necessitating a replacement of the valve. If it is the suction service valve, one must remove all the refrigerant from the cooling unit and then balance the pressure unless the cooling unit is furnished with valves. To remove a discharge service valve or a liquid receiver service valve, the refrigerant must be removed from the entire system. Do not pinch the lines to replace valves as the weakened tubing will shortly cause trouble. Servicemen have successfully replaced these valves by super-cooling the refrigerant in the system by using dry ice. When dry ice is packed around the refrigerant containing parts of the system and when the gauges show atmospheric pressure, the system can be opened. Be sure to wear goggles during this operation.

11-18. REMOVING THE ELECTRIC MOTOR

To remove the electric motor, first

disconnect the power line, then remove the wires from the motor terminals. Label the terminals to aid assembly later. Next loosen the hold-down bolts which attach the motor to the base. Remove the belt from the flywheel first, then the pulley. The motor can then be lifted out. Use care that the fan does not hit the condenser coils or catch on the belt.

11-19. REPAIRING THE CONVENTIONAL UNIT

Most of the mechanisms used in conventional refrigerating machines may be repaired and used again just as is done in automobile repairing. However, the replacement policy is very popular and if the parts are available, this practice is to be preferred. Many orphan makes (the manufacturers are no longer in business), are still being used and parts cannot be obtained for them. With these machines in mind, the following instructions deal with reconditioning the old mechanisms to efficient condition. There are many things that can go wrong with a refrigerating unit but only a few represent 90% to 95% of the failures. These few are (1) leaks (2) faulty motor (3) faulty compressor and (4) faulty refrigerant control. The overhaul of the electric motor is covered in Chapter 7. Leaks are discussed in Chapters 8 and 11.

11-20. CHECKING THE COMPRESSOR

Many refrigeration troubles are due to compressor failure. In most cases of refrigeration failure, it is advisable to check the compressor first to determine if it is operating satisfactorily. Naturally, a good service man will also look for other indications of troubles as he performs the check on the compressor. However, he should be certain that the compressor is in satisfactory operating condition before proceeding with other tests.

The two most common causes of compressor trouble are valves, and seals. Noisy valves may be detected by a sharp clicking noise in the compressor as it operates. Leaky valves may be detected as follows: install both the high pressure and compound gauges or the gauge manifold and test for leaks. Turn the suction service valve stem all the way in to close the suction line and then run the compressor intermittently. That is, turn the power on and off for a very few seconds at a time until the danger of pumping oil is stopped; then allow the compressor to run until a 28 inch vacuum or as good a vacuum as possible, has been obtained. Stop the compressor; if the compressor exhaust valve leaks, the high head pressure will leak back through the exhaust valve and produce a pressure above atmospheric on the compound gauge; therefore if the compound gauge creeps, it is a sign that the exhaust valve needs servicing, or that there is a leak on the low side (seal).

Another way to check the efficiency of the exhaust valve of the compressor is as follows: Mount the pressure gauges, test for leaks, and then turn the discharge service valve stem all the way in. TURN THE COMPRESSOR OVER BY HAND. If the discharge valve leaks, the pressure, as indicated on this pressure will then leak back to its former value as the piston goes down if the exhaust valve is leaking. That is, if the gauge pressure fluctuates considerably, it is an indication of a leaky exhaust valve, but if the pressure merely increases and does not drop back to any extent, it indicates that the exhaust valve is not leaking.

A worn piston or cylinder is indicated by a clicking noise which is somewhat duller than the noisy valve indication mentioned before. A compressor should be able to produce at

least 30 inches of vacuum against its head pressure (depending on the refrigerant) to be good enough for use. The compressor must pump a specified quantity of gas at a certain pressure difference to do the work necessary; but this is too hard to check; therefore the above methods are used as secondary checks. See paragraph 21-44 for a description of compressor volumetric efficiency. Many shops use a fixed size tank into which the compressor pumps air while being tested. If the time it takes to pump the compressor pumps into 150 lbs. per sq. in. is noticed for each size a compressor, a universal way to test volumetric efficiency is available.

Compressor Testing Methods:

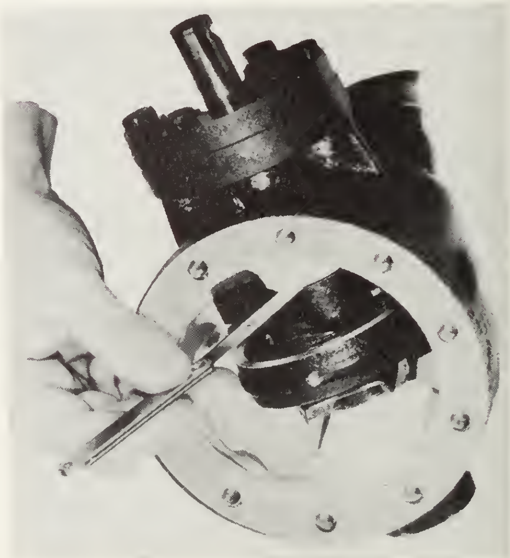
1. Vacuum producing ability
2. High pressure maintaining ability
3. Being able to hold both the vacuum and the head pressure

11-21. CHECKING COMPRESSOR SEAL LEAKS

To test for leaks on the low pressure side of a compressor, such as at gaskets, at the suction service valve, or at the crankshaft seal, one may use one of two methods: (1) Close the suction service valve and draw as high a vacuum on the compressor as possible. Then turn the discharge service valve all the way in. Keep the compressor running. If the head pressure gradually rises, it means that air is being drawn into the low side of the system. (2) A better way is to balance the pressures in the crankcase and turn the discharge service valve all the way in. Remove the discharge service valve gauge plug and connect a 15 in. length of copper line; then immerse the end of the copper line into a glass bottle partly filled with oil, with the compressor running. If the tube discharges gas continuously, as shown by air bubbles appearing in the oil, air is being admitted to the low side of the compressor. If there are no leaks, the bubbling will stop immediately after the compressor is started. To locate the leak, put refrigeration oil around one joint at a time; if air is leaking in at that point, the air bubbles will cease while the oil is being drawn in instead of air. See Fig. 11-12.

11-22. COMPRESSOR INTAKE VALVE TESTING

A poor intake valve will be indicated by a poor vacuum, but the compressor holds it when it stops. This may also be due, however, to too thick a gasket or worn pistons and rings. Another item



11-11. This figure illustrates the correct method of measuring clearance between the crankshaft eccentric and the compressor housing.
(Tecumseh Products Co.)

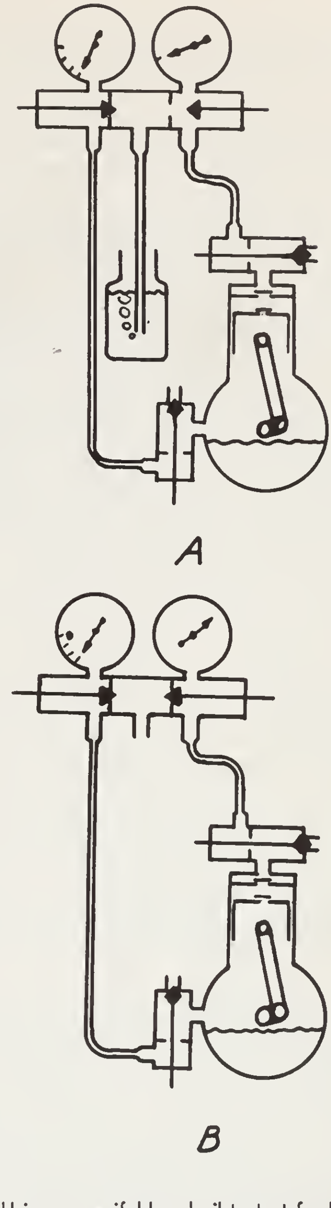
to keep in mind is that a lack of oil will always result in poor pumping ability.

When assembling a compressor in which it has been necessary to replace major parts it is important that the eccentrics be properly positioned on the crankshaft. The eccentrics must be positioned so the connecting rods are

given a full seat on the eccentrics; also sufficient end clearance must be provided in order that the eccentrics will not bind or rub against the compressor housings. Fig. 11-11 shows the correct way to measure clearance between the eccentric and the compressor housing.

11-23. COMPRESSOR TESTING AFTER OVERHAUL

After the compressor has been overhauled, it should be charged with the correct amount of oil and tested. To put the proper amount of oil in a compressor, connect a tube to the suction service valve, run the compressor, and pump a vacuum with this tubing immersed in fresh refrigerant oil. The oil will quickly fill the crankcase. Oil starting to spray through the discharge service valve, is an indication that the compressor has enough oil. It is best to fill the compressor with the amount of oil recommended by the manufacturer. The compressor should next be equipped with a high pressure gauge and a compound gauge, or a gauge manifold vacuum against its head pressure (75 psi for sulphur dioxide and 100 psi for methyl chloride). If the compressor tests all right, it should be baked for a period of 8 hours or more at a temperature of 150 F. to 200 F. with a 20 in. vacuum on the crankcase.

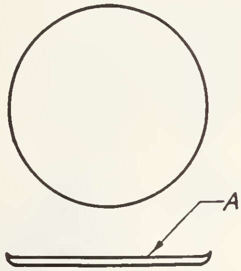


11-12. Using a manifold and oil to test for low pressure side leaks in a compressor. A. The bubble test. B. The head pressure test.

11-24. REPAIRING COMPRESSOR VALVES

Practically all valves of domestic refrigerators are of the diaphragm or disk type, usually called a flapper valve. They are made of very thin spring steel with a smooth surface and are held in place either by their own spring tension and a machine screw, or by an auxiliary coil or flat spring. After a long period of use the compressor valves wear and the valve seats, which are usually made of cast iron, may become worn. It is always a good policy to replace the valves when overhauling a compressor because the cost is small. It is also good practice to lap the valve seats. There are many methods of lapping seats that are satis-

factory. The two things necessary are that a very fine lapping compound be used and special care must be taken to clean all lapped surfaces carefully after lapping valve seats, otherwise the compound will ruin the compressor. Wherever raised valve seats are used, a plate glass surface may be used as the lapping tool, or special lapping blocks may be used. Some companies use fine polishing paper clamped to a flat plate as the lapping surface. Where the valve seat is in a bad condition, the valve plate should be mounted in a lathe, either in a chuck or on a face plate, and the whole plate trued up. Most companies also use a surface grinder to true up a valve seat.



11-13. A valve disc. The side (A) is to face away from the valve seat.

In compressors using the spring steel type of valve it is necessary that the proper surface of the valve come in contact with the valve seat. This surface may be detected by the slightly turned-over edge of the opposite surface of the valve. This is caused when these valves are stamped out; the stamping process turns the edge of the valve on one side (burrs it) and if this side were placed against the valve seat, it might not seal properly, Fig. 11-13.

Replacement valve plates are available and their use is recommended in the field. One replacement valve plate has removable seats and valves, Fig. 11-14.

11-14. A replacement valve plate. These special valve plates are available for most refrigeration compressors. The valves and the valve seats are removable and can therefore be easily repaired.
(Chicago Seal Co. Inc.)

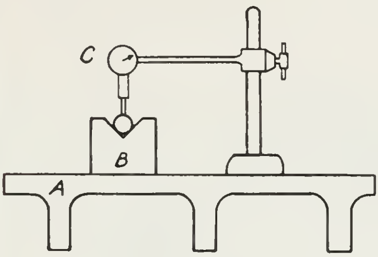
11-25. REPLACING BEARINGS

It is seldom that any work has to be done on the connecting rod bearings or crankshaft bearings of compressors, but if this should be necessary, it is a replacement and reaming process similar to some automobile work. Old bearing sleeves usually made of brass or bronze are removed by first splitting them with a cape chisel. The new sleeve is pressed into place and then line reamed to fit.

A bushing pressed into a blind hole can also be removed by using hydraulic pressure. Fill the cavity with grease and then insert a shaft the same size as the I.D. of the bushing. Cover the shaft with a cloth to protect against flying grease and then hit the shaft a sharp blow. The hydraulic pressure created will push out the bushing.

Always measure the crankshaft journals for size, taper and out-of-round. A variation of more than .001 inch necessitates reconditioning the journal or replacing the crankshaft, Fig. 11-15. Very close clearances are

usually held in fitting compressor bearings. One of the most common sources of noise in a compressor is the piston pin. This pin must be replaced in practically all overhauls. Tolerances of .0005 in. are not too small. The fit must be very snug. Adjustable reamers, hand operated, may be used to ream the piston and connecting rod. If the pin itself is badly worn, a new one must be obtained. Some automobile piston pins are usable in refrigerating compressors. Badly scored eccentric connecting rods must be replaced.

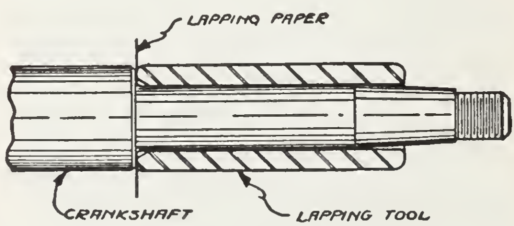


11-15. A method of checking shafts, rollers and cylinders for trueness. A. Surface plate; B. Vee Blocks; C. Dial indicator.

11.26. REPAIRING CRANK SHAFT SEAL

Sylphon seals usually have only two troubles, a squeaky noise caused by running the seal dry, and a leaky seal caused by a scored seal surface. A noisy seal will soon become a leaky one if not attended to: it may be remedied by the usual process of lapping the seal, or it may sometimes be repaired by tapping the seal box lightly with a hammer. A more certain remedy is to wrap the bellows with oil-soaked wool yarn or string. A leaky seal may be detected by the usual test for leaks (ammonia for sulphur dioxide, etc., See Paragraph 11-37). Air in the system is usually the result of a leaky seal. This is detected by a high head pressure in systems having a below atmospheric low side pressure. It will usually cause a lack of refrigerant in systems using an above atmospheric low side pressure. The usual symptoms of this trouble are high power bill, constant running, poor refrigeration.

To lap in a sylphon seal properly, the work should be done with a special tool made of case-hardened steel with a ground surface. This tool with some oil-saturated lapping compound of a very fine texture is all that is necessary. The crankshaft surface and the surface of the sylphon that come in contact should never have any scratches on them and should be of a burnished appearance to give satisfactory service. The contact surfaces of the sylphon and the crankshaft shoulder must be perfectly square and polished. See Fig. 11-16, Fig. 11-17 and 11-18. A scored crankshaft seal shoulder is best repaired by putting the crankshaft in a lathe and polishing the shoulder face with a high speed grinder. The amount ground away must be very small because the case hardening on these shafts is only .015 in. to .030 in. deep. Once this case hardening is ground through, the seal will not wear long. After the shaft is ground, it must be lapped in the lathe, using phosphor bronze or cast-iron lapping blocks and a very fine lapping compound under a light, even pressure.



11-16. Lapping the crankshaft seal shoulder.

When assembling a new or a rebuilt seal a special tool should be used to align the seal mechanism so it will be

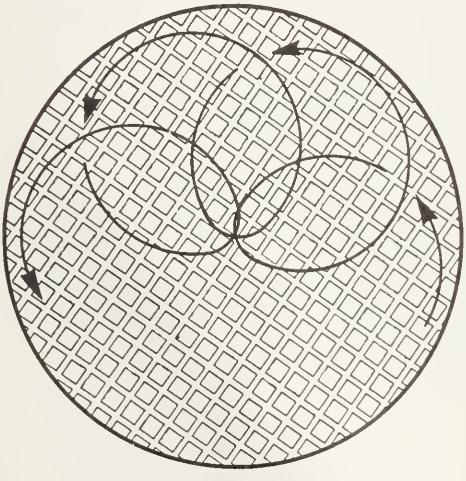
located in proper position in relation to the crankshaft and seal housing. Fig. 11-19 illustrates a seal alignment tool.

Many service men use replacement seal assemblies. These assemblies

11-17. The equipment and supplies needed to lap seals and valve plates. Note the magnifying glass used for inspection.
(Norge Sales Corp.)

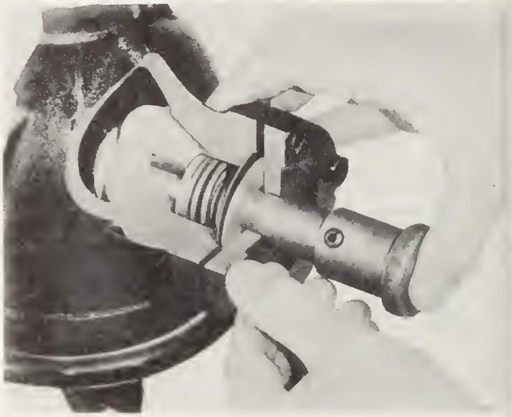
eliminate grinding and polishing as the kit replaces both the crankshaft shoulder and the seal ring. See Figures 11-20 and 11-21.

Always use new gaskets when assembling a compressor as the old gaskets have lost their compressibility.



11-18. The correct lapping motion when lapping seal faces or valve plates.
(Norge Sales Corp.)

Lead or special paper gaskets are used on compressors. The lead gaskets are considered best, but they cost more. The thickness of the lead is between .010 and .020 in. The paper gaskets when used, must be of the same thickness as those removed and must be thoroughly dry (dehydrated). When making a gasket, it must fit the chamber to be sealed. That is, the gasket that is placed between the exhaust valve plate and the cylinder must fit the cylinder with not more than 1/32 in. clearance. If this distance is made larger, it reduces the efficiency of the compressor materially because it increases the clearance volume. The gasket must also be exactly the same



11-19. A seal alignment tool.
(Tecumseh Products Co.)

thickness as the original gasket. A gasket that is too thick will reduce the compressor efficiency, and too thin a gasket may cause an annoying knock.

In case a compressor has been frozen due to a high head pressure or moisture in the refrigerant, it should be very carefully cleaned and the piston and cylinder especially should be burnished in order to remove all foreign substances. Xylene will loosen a stuck-up sulphur dioxide compressor very nicely. Whenever a compressor is overhauled, new refrigerant oil should

be replaced in the crankcase unless the old oil is not discolored. The compressor must be thoroughly dehydrated (baked) for 8 to 24 hours at 200 F while subjected to a deep vacuum before it is used.

11-27. REPAIRING CONDENSER AND RECEIVER

When trouble is encountered with either a condenser or a receiver, it is usually cheaper to replace the unit than to repair it. This is also true in regard to the cooling unit unless the flooded system is used. Welding, brazing, or soldering is sometimes used to repair leaks in the system, but it requires careful work. If possible, all joints should be silver brazed to insure a lasting leak proof joint.

11-28. REPAIRING COOLING UNIT

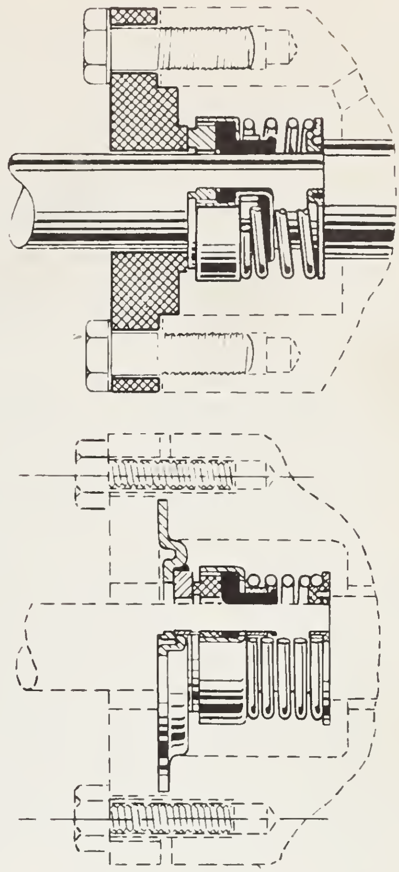
In the flooded system the cooling unit trouble is most common in the float mechanism. It is recommended that this unit be replaced rather than a repair attempted.

The coil itself may be injured in such a way as to leak. In this latter case repairs should be made with a high tin solder (95-5) or the work should be done with silver alloy.

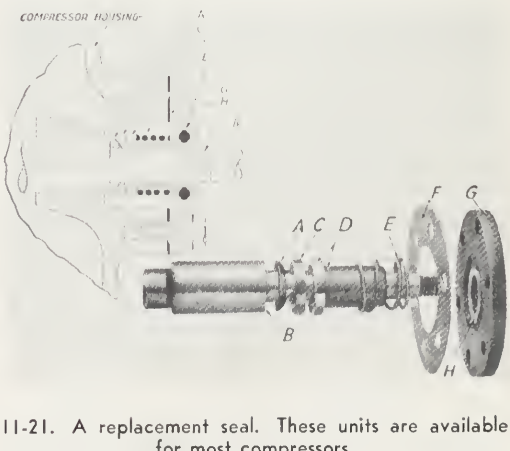
It is necessary to point out here, however, that occasionally a service man will be led to believe that there is something seriously wrong with a part of the refrigerator when it is only some very small part such as a clogged screen or a pit in the needle valve seat.

11-29. REPAIRING EXPANSION VALVE

Four things likely to go wrong with an expansion valve are: the needle and seat becoming worn, a dirty screen,



11-20. Replacement seals for conventional compressors. Seals of this type are also found on many new compressors.
(Rotary Seal Co.)



11-21. A replacement seal. These units are available for most compressors.
(Chicago Seal Co.)

leaky bellows, moisture accumulation on the outside of the bellows. Occasionally, one finds such trouble as a broken spring, etc., but it is rare and is easy to locate. A worn needle and seat is usually due to a lack of refrigerant in the system. The refrigerant does not have a chance to condense before it passes through the expansion valve orifice and this dry, hot gas cuts or erodes the needle and seat very rapidly.

The best repair of a needle seat is to replace it with new parts. If replacements are not available, the needle must be reground or restoned in a lathe or drill press until the shoulder that has been worn into the needle surface disappears. It is very important that the same taper be kept on this needle point. The seat, which is nearly always made of a softer metal than the needle, may usually be filed, with a dead smooth file, until the older surface against which the needle was seated has disappeared. The seat must be filed square at right angles to the center line of the needle. A file guide is best for this purpose.

One may tap the new needle into the new seat during assembly of the valve and get good results.

A leaky bellows is due either to breaking down of the soldered joint, or to a fracture in the bellows itself. It is a difficult thing to repair, without a special fixture to hold the parts. The correct thing to do is to replace the expansion valve. However, clever soldering may sometimes be done to repair the trouble. When soldering is done on an expansion valve, the bellows must be immersed in water to keep it cool. It is difficult to find the location of the leak in some particular instances. The following method will be found useful: Connect the expansion valve to a dry air line and build up a pressure of 10 to 15 pounds on the low side of the expansion valve by plugging the low side opening. Immerse the whole expansion valve in a quantity of oil or in some high flash paint solvent; the leaks will be indicated by bubbles.

The matter of successfully cleaning a screen is quite important. Fine-mesh copper screens may be cleaned fairly successfully by combining air pressure and a safe solvent, too, but, the best way is by heating it. This must be very carefully performed or the screen will be burned. It is important never to allow an expansion valve to go into service without a screen being placed in the liquid line entrance.

Moisture on the outside of the bellows is a result of air leaking into the housing surrounding the bellows and the natural condensation of the moisture in the air upon the cool surfaces. This moisture, when it freezes, binds the bellows and does not permit the expansion valve to operate at all, or permits only very erratic operation. Washing this part with a moisture absorber removes the moisture and prevents the reoccurrence of the trouble. The service man may do three things: (1) Put a quantity of vaseline in this space which will not allow moisture to accumulate. (2) Put a quantity of glycerine in this chamber which will combine with any moisture that enters and form a non-freezing mixture. (3) Place a rubber cap over the open end to exclude the air. The rubber cap usually is adequate and is the most common practice.

To test an expansion valve after it has been repaired, one may use the following system: Join the liquid line connection to a dry air line and create at least a 90-pound pressure at the expansion valve. Turn the adjusting nut in until the valve is opened and permits the air to come through; then turn it out again until air ceases to pass by the needle. To test this accurately, pour some refrigerant oil in

the cooling coil connection or low side opening of the expansion valve. If the valve is leaking, bubbles will be formed. No leak of any size should be permitted.

Another way to test an expansion valve is to connect a compound gauge into the low side of the valve and a high pressure line on the liquid line connection.

With the air fed into the liquid line opening, an increase of the pressure on the compound gauge will indicate a leaking valve.

If a hand needle valve is used in the low pressure side opening in parallel to the gauge a definite amount of air can be released and one can tell if the expansion valve needle is sticking. Any variation of pressure at the compound gauge will show that the needle valve is leaking. See Fig. 11-22.

The compound gauge will give the various low side pressures for the different adjustments and will also indicate if the valve is leaking.

To test the bellows for leaks at this point, plug the low side opening of the expansion valve, then turn the adjusting screw in until a positive pressure of at least 30 to 40 pounds is produced on the inside of the bellows. Any leaks in the bellows will be indicated by bubbles coming through the oil that one places over the adjusting screw opening of the valve.

11-30. REPAIRING FLOAT VALVES

The four things that most commonly occur as troubles with low side float valves are: a leaky needle and seat, a clogged screen, a leaky float, and the float mechanism out of calibration. The needle and seat are repaired precisely as those of the expansion valve explained above. This also applies to the screen.

It is a very difficult trouble-shooting operation to locate a leaky float ball. A very small pin hole in a float will permit the refrigerant to enter the interior of the float slowly and weigh it down. This will result in the needle being held open all the time. The best way to test a ball type float for a leak is to immerse it in very hot water. Do this very gradually so as not to disturb the water; the air on the inside of the ball on becoming heated will expand and come from any leak that may be existent in the ball. To solder a pin hole, the ball must be preheated.

One of the most difficult repair jobs is the calibration of the float. By calibration is meant the level of the float needed to close the orifice. If the float level is too low, the unit will short-cycle in case of a pressure control, or will give an unsatisfactory box temperature in case of a thermostatic control, because the area of evaporation of the refrigerant will be reduced.

About the quickest way to test a low side float is to mount the float in an almost vertical position, just enough off vertical so that the float tends to keep the needle pressed lightly against the seat. Be very careful not to allow the float to lean over to one side. Connect the liquid line opening to a dry air line and build up a 90 pounds per square inch pressure in it. Put some refrigerant oil around the needle and seat; the appearance of bubbles will indicate a leak. If the needle is leaking just a little, a light tap on the needle will sometimes seat it firmly in its seat and it will give satisfactory results. Remember, however, that this sort of repair should only be done in case one knows that the needle has no shoulder on it and that the seat is not too wide.

11-31. REPAIRING HIGH SIDE FLOAT VALVES

There are three principal types of high side float systems used in domestic refrigeration. The type that uses

the high side float located near the cooling unit has troubles very similar to the low side float mechanism. The only difference one must keep in mind is that the operation of the mechanism is opposite to the low side float. In the other type of high side float system, where the high side float is located in the liquid receiver, and where a weight check valve is used between the liquid line and the cooling unit, the following troubles may be incurred. (1) As for the float itself, the troubles are naturally similar to the low side float troubles and the methods of repair may be considered the same. (2) However, the weight check valve lends an additional servicing problem. This valve may be either stuck open or stuck closed. In the first case a decided frosting of the liquid line will be the indication of trouble. If the needle is stuck closed, naturally one will get no refrigeration and a compound gauge will indicate a high vacuum on the low side. Then if one cracks the fitting connecting the liquid line to the weight check valve and finds liquid refrigerant at this point, it will show that the weight check valve is the trouble. These valves are very small and inexpensive and one should replace them as often as necessary; however, in case a new one cannot be obtained, these valves may be dismantled by either unsoldering or unbolting them, and the repair of the needle and seat is similar to what has been explained above. To test this valve, it is best to try to force the air backward through the valve. Be very careful to keep the valve right side up.

(3) High side floats are sometimes used with capillary tubes. This combination permits locating the high side float remote from the cooling unit and the capillary tube keeps the liquid from frosting. In addition to the regular float troubles, the capillary tube may become clogged or moisture may freeze it closed.

One trouble encountered in the high side float is that overcharging will flood the low side with refrigerant, frosting the suction line and perhaps the compressor base.

11-32. ASSEMBLING REFRIGERATING UNIT

When the repairs have been made, and the parts, after a rigorous testing of them, are considered all right, the problem of assembling the apparatus to insure correct operation is very important. Only a careful observance of certain fundamentals will make possible an assembly which will assure an efficient running unit. The four fundamentals to be followed when installing a part of a refrigerating mechanism are: (1) Clean and dry the part to be put in the system. (2) Purge and evacuate that part of the system which has been opened. (3) Test for leaks. (4) Start and adjust the unit.

If a compressor overhaul has just been completed, the installation of the compressor must be very carefully done or the repair job will be unsatisfactory. After bolting the compressor to the base and lining it up with the electric motor so that the belt is installed properly, bolt the suction service valve and the discharge service valve to the compressor. Install the gauges or the gauge manifold gauges in the suction service valve, remove the plug on the discharge service valve, and exhaust the compressor to the outside until a vacuum of 25 to 28 inches has been drawn upon the crankcase for several minutes. Care should be taken to guard properly against oil being thrown from the discharge service valve. If the compressor pumps oil, a cloth or sponge held over the discharge service valve opening is usually sufficient. In case a gauge manifold is used

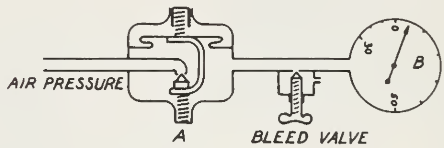
the center opening should be led to a container with a 1/4 in. O.D. line.

After a sufficient vacuum has been drawn, the compressor should be heated thoroughly with a torch in order to expel all traces of moisture and air. The temperature for this should be upwards of 200 F. To complete the operations of putting the compressor in service, crack the suction service valve slightly and allow some refrigerant to escape into the crankcase until a 5 to 30 pound pressure is obtained. Then test very carefully for leaks. Close the suction service valve completely and with the discharge service valve still closed, start the compressor and evacuate again to a 25 to 28 in. vacuum. This evacuation should be to the open air of the room or piped to the outside and not discharged into the condenser. The discharge service valve is turned all the way in during this operation.

After the second vacuum has been drawn, replace the high pressure gauge in the discharge service valve; open both the suction service valve and discharge service valve all the way out, but not far enough to close off the gauge openings. As this is done, it is a good policy to start the compressor again; otherwise there might be a flow of liquid refrigerant from the cooling unit to the crankcase of the compressor. This may cause a freezing condition when starting the compressor. The presence of liquid refrigerant may also cause pumping of oil which may break the compressor valves.

Because it is virtually impossible to assemble a refrigerating mechanism in the field without having some foreign matter (dirt and moisture) get into the system, it is highly recommended that a dryer (Paragraph 20-42) be installed in the system.

Leave the gauges attached to the mechanism until the expansion valve has been adjusted to the correct operating pressure and also check up on the condensing pressure which will tell whether the unit is working correctly. It is desirable that the gauges be left on for at least twenty-four hours, so any unusual trouble may be detected. This practice is usually not possible. In this event, a service call should be made within the next day or two to check on the operating pressures, and the general condition of the refrigerator. When available, temperature and pressure recorders may be connected into the system for 24 hours to guarantee correct unit operation.



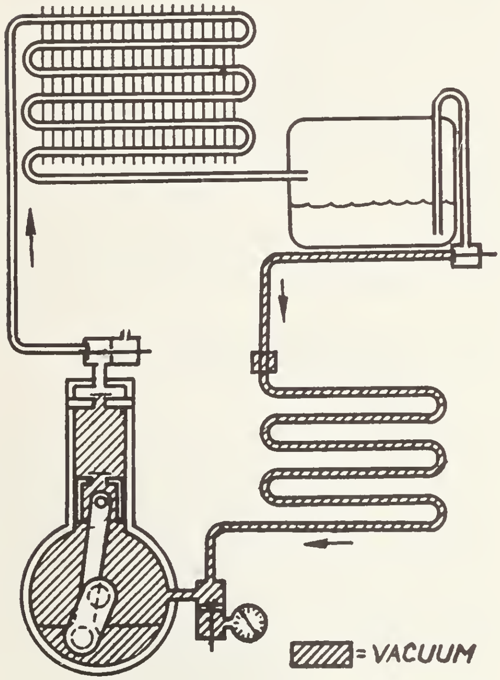
11-22. A method used to check an expansion valve for leaks and for pressure setting.

11-33. INSTALLING COOLING UNIT

In the event the cooling unit has been removed, several important things must be remembered during the assembly in order that the apparatus function properly. After bolting the cooling unit back into the refrigerator and leveling it, remove the plugs on the refrigerant openings and attach the liquid line and suction line to the cooling unit. Be very careful during these operations that no moisture enters the lines. It is good practice to dry the surfaces of the lines and cooling unit before removing these seals.

If the cooling unit is of the dry system, the expansion valve should be installed using a new gasket if it is of the bolted type. This ruling should be maintained on all refrigeration overhauls because it is taking a foolish chance to use old gaskets when the installation of new ones costs so little.

To continue with the installation, loosen the compressor end of the suction line and crack the expansion valve allowing some refrigerant to escape forcing the air out of the cooling unit and suction line. The compressor end of the suction line should now be tightened. Another method is to evacuate the cooling unit, suction line, and compressor twice to the air; the trapped air will then be drawn out of the system. The discharge service valve must be



11-23. An illustration showing the compressor evacuating both the liquid line and low pressure side to the open air.

turned all the way in during the evacuation, and the gauge plug removed, Fig. 11-23. Test for leaks with a 5 to 25 psi pressure and test for leaks again at a 200 to 225 psi before allowing the refrigerant to escape into the unit.

The cooling coil may be dehydrated more completely by heating it to a fairly high temperature of (175-200 F.) as it is evacuated to drive out any moisture that may be present.

If a flooded system cooling unit equipped with service valves is used, bolt the valves to the unit, open the suction valve, and evacuate to the outside. Crack the liquid line valve, test for leaks, and evacuate again. This will clean the system of air. Close the compressor exhaust opening, open the cooling unit liquid valve, and the unit is ready to operate. In a case in which the cooling unit is not equipped with valves, the liquid receiver service valve must be used as the purging valve.

11-34. INSTALLING EXPANSION VALVE

Mount the expansion valve and evacuate the liquid line, the cooling unit, and the suction line. Test for leaks carefully by purging and then evacuate again. Close the expansion valve, open the liquid receiver valve, start the compressor, and adjust the expansion valve to the correct low pressure. If the expansion valve is left open when the liquid receiver service valve is opened, the compressor crankcase will be flooded, lengthening the time of the service call unnecessarily.

11-35. INSTALLING FLOAT VALVE

Install the float valve, evacuate, purge, and then test for leaks. Evacuate again and then seal the compressor, open the liquid receiver service valve and start the compressor. Be sure that there is some oil in the float valve or the float will not be adjusted right (one-quarter pint of oil is usually sufficient).

11-36. SUMMARY OF REFRIGERATOR MECHANISM REPAIRING

If the above instructions have been studied carefully, the student should

recognize the following important things:

1. It is necessary to remove the refrigerant from that part of the mechanism to be overhauled.

2. It is necessary to equalize pressures in the unit before dismantling or there will be a rush of air into the unit or of refrigerant out of the unit upon breaking the lines.

3. It is necessary to plug all refrigerant openings immediately after dismantling.

4. It is necessary to put in new gaskets wherever they are used.

5. It is necessary, upon reassembling, to remove all the air and moisture from the lines and whatever part that has been open to the air; this may be done both by evacuating and purging.

6. To remove any part of the system it necessitates the closing the closest valve between that unit and the liquid receiver tank, and evacuating the unit by means of the compressor into the condenser and liquid receiver tank. If more than one method is available to do the operation, the best one naturally is the one that can be done in the shortest possible time because lingering on the job only adds to the inconvenience of the people in the residence where the work is being done. Always remove any tedious task to the shop to be worked on and, in the meantime, replace the unit with a temporary unit in order that the owners may still have the use of their refrigerator.

11-37. TESTING FOR LEAKS

After any installation, or the replacement of any part of the refrigerator circuit, it is absolutely necessary that a very rigid test be made of all the joints to make sure that they are leak-proof. The methods of testing for leaks vary with the different refrigerants used. However, they are common in this respect: a positive pressure (greater than atmospheric) of from 5 to 30 pounds is necessary throughout the circuit in order that one may test for leaks.

11-38. TESTING FOR SULPHUR DIOXIDE LEAKS

A very efficient test for a sulphur dioxide leak is an ammonia swab, that is, a small piece of ammonia-soaked cloth fastened to the end of a stick. The ammonia must be quite strong, the minimum strength being 26 per cent. This is stronger than household ammonia and one may obtain it at the refrigeration wholesale house or at a local drug store. Place this swab adjacent to joints or places where leaks may occur; if there is a leak, it will be made noticeable by a thick white smoke forming at the joint. BE VERY CAREFUL NOT TO TOUCH THE METAL WITH THE AMMONIA AS IT WILL CORRODE THE FITTINGS.

The neatest method is a double pressure test especially if the testing is being done in the owner's home. First, produce a pressure of 3 to 5 pounds throughout the low pressure side of the system and test for leaks. If one is present this low pressure will cause the escape of very little refrigerant before the leak is detected. Increase the pressure up to 30 pounds and test again. Occasionally a leak is found at this higher pressure which is not detectable at the lower pressure. If the service man were to test immediately 30 pounds pressure, there might be such a bad leak present that the entire room would become filled with the refrigerant before he had a chance to stop it and it would also cause the leak of so much of the refrigerant that the exact source would be hard to detect. The final test for leaks should be done at 100 to 200 psi.

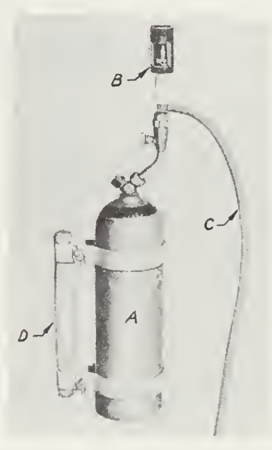
The American Society of Refrigerating Engineers in their American Code

specify test pressures for all refrigerants (Chapter 29). It is recommended that the service man follow these pressure test standards.

11-39. TESTING FOR METHYL CHLORIDE AND ISO-BUTANE LEAKS

If the refrigerator uses methyl chloride, the method of finding a leak is quite different. First, all the grease and oil must be removed from the joint suspected of leaking; then, using a very thick soap suds and water solution or oil, test all around the joint for a leak. If bubbles are formed, refrigerant is escaping. In case the unit under test is not hooked to the refrigerating circuit, it may be tested by submerging it in a water bath after it is put under a thirty or forty pound pressure. That is, a test similar to testing leaky automobile inner tubes may be used. A small mirror and a flash light may be used to inspect inaccessible places.

Test all joints carefully because even a minute leak will cause a complete loss of the refrigerant in a relatively short period. The halide lamp is not recommended for testing for methyl chloride leaks as the gas is explosive in some concentrations.



11-24. A halide torch used for testing for leaks. Note the small acetylene cylinder, (A) the handle, (D) the air intake, (C) and the shielded copper element (B). (Linde Air Products Co.)

11-40. TESTING FOR AMMONIA LEAKS

In the ammonia system, such as the absorption type, two methods for testing leaks may be used. One is a sulphur candle whose flame will give a very thick, white smoke if it comes in contact with leaking ammonia, and the other is to test with moist phenolphthalein paper, which will change its color instantly upon coming in contact with ammonia. Both of these tests are very rapid, convenient, and accurate. The paper method is safer.

11-41. TESTING FOR FREON, CARRENE, AND ETHYL CHLORIDE LEAKS (HALIDE TORCH)

To test Freon (F-12) F. 22, Carrene, or ethyl chloride, for leaks, a good method has been devised, but it requires special equipment. It is an alcohol (halide) torch with a long air intake tube. With this alcohol torch ignited, pass the intake tube near the different joints. If some gas is leaking out it will go up the intake tube to the flame and give forth a brilliant green hue, a sure indication of a gas leak. A halide torch should be filled with alcohol and pumped up with air out-of-doors or in a room in which there is no possible chance of gaseous refrigerant being present; otherwise, if some refrigerant were pumped into the torch in charging it, it would give a continuous indication of the presence of a leak and would therefore be of no use in detecting leaks in a refrigeration mechanism. The alcohol used must be exceptionally clean as the small liquid passages are very small. To light one of these torches, the flame chamber must be preheated and the air intake tube

opening stopped with one finger until the flame is burning well.

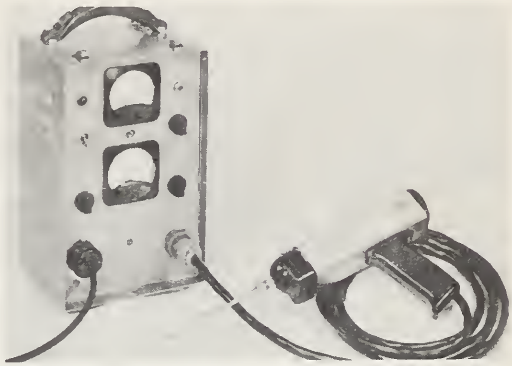
The halide leak detection may also use natural gas, acetylene, or propane as the fuel. Fig. 11-24 shows a halide leak detector using acetylene as the fuel. These gases may also be tested for leaks by the soap solution method or by immersion in water.

The most sensitive leak detecter is the electronic leak detecter, Fig.11 - 25. It measures the electronic resistance of gas samples and if the refrigerant is in the air sample being tested the current flow changes. The change in current flow indicates on a milliammeter or rings a bell.

11-42. CHARGING REFRIGERATOR

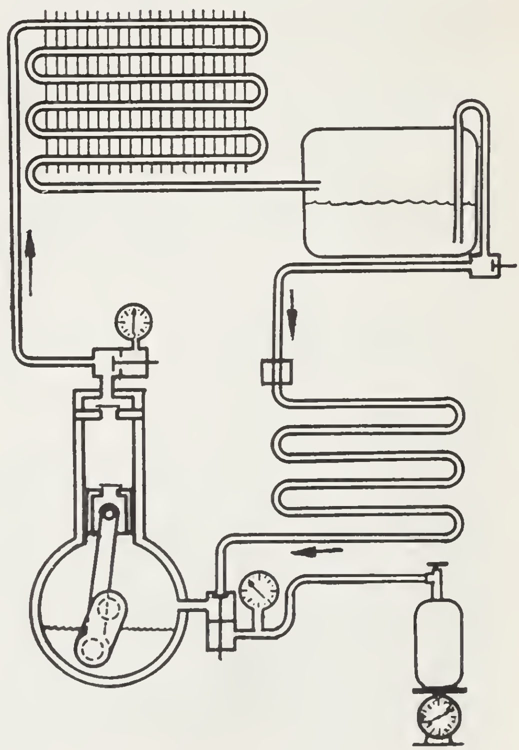
All of the conventional compressor type refrigerators are charged with refrigerant in the same general way. The easiest and most used method is to charge into the low side of the cycle. This may be done as follows: Turn the suction service valve until the gauge opening is closed. Clean the valve, remove the gauge plug, install a T fitting in the service valve and fasten a low pressure gauge to the fitting. Attach a line from a charged refrigerant cylinder to the other opening of the tee fitting. A gauge manifold may also be used for this operation.

A horizontal tubing must be used here which should be at least 4 feet long in order to permit accurate weighing of the refrigerant. Fig. 11-26. Purge this line as follows: leave the fittings at the suction service valve end of the line loose, crack the cylinder valve, and the escaping refrigerant will remove the air from the line after which the joint may be tightened. TEST FOR LEAKS. Turn the suction service valve all the way in, so the suction service line is closed. Place the refrigerant cylinder on a scale in order that the quantity of refrigerant removed from



11-25. An electronic leak detector. (General Electric Co.)

it may be weighed. The cylinder must be held in an upright position while dis-



11-26. An illustration showing a setup for charging refrigerant into the low pressure side of a system. Note the provision for weighing the refrigerant.

charging into the compressor. Start the compressor, and operate it until enough refrigerant has been removed from the cylinder into the unit. Control the low side pressure by opening and closing the cylinder valve. Always keep the pressure above a vacuum. The cylinder may have to be warmed with hot water to maintain a positive pressure. Never use a torch as overheated cylinders may explode. Close the cylinder valve and stop the compressor after the scales show that enough refrigerant has been added.

Remove the cylinder by turning the suction service valve all the way out so the gauge opening is closed and remove the line. The pressure in the line should be balanced before opening the lines. Install a compound and a high pressure gauge and start up the unit. The gauges will indicate whether the unit is operating correctly or not. Adjust the pressures and test for leaks. Then remove the gauges, install the plugs, and the refrigerator is ready for use. The use of a gauge manifold saves considerable time on this job.

Another method of charging a refrigerator is to attach the line from the charged cylinder to the gauge manifold opening of the discharge service valve and to drive the refrigerant out of the cylinder by increasing the pressure in the cylinder above the pressure in the system. THE CYLINDER MUST BE INVERTED.

A pressure can be built up in the refrigerant cylinder by turning the discharging service valve all the way in with the suction service valve open and running the unit. This will build up a high pressure in the cylinder while the condenser is cooling. Stop the compressor, then turn the discharge service valve out a few turns. The pressure will force the liquid into the condenser and liquid receiver. Some service men create this pressure by heating the cylinder. THIS PRACTICE IS NOT RECOMMENDED.

Many service men are using disposable refrigerant cylinders for service operations. These cylinders insure clean, and dry refrigerant and eliminate the need to transfer from larger cylinders to small ones, Fig. 11-27.

11-43. REMOVING AIR FROM CONDENSER

After charging the refrigerator mechanism it is well to go back in a day

11-27. Disposable containers for refrigerants. These factory charged containers insure clean and dry refrigerants.
(Eston Chemicals Div.)

or so and check the operating pressures again, because there is a chance that air may have leaked into the system. Air in the system will be indicated by an above normal head pressure even after the unit has cooled down. It may be removed by cracking the gauge opening on the discharge service valve while the unit is idle.

A tube fastened to the gauge opening should be led out-of-doors to avoid releasing the fumes in the house. A purge of 10 to 15 seconds will be of sufficient duration to remove the air if the condenser is cold. This complete removal is possible because the air is non-con-

densable; therefore it will collect in the top of the condenser as the lower end is sealed with liquid refrigerant. If it is an irritant gas, the purging line should be run outdoors or into a sewer and washed down with running water.

11-44. TRANSFERRING REFRIGERANTS

It is good economy to purchase refrigerants in 50-lb. and 100-lb. quantities. This practice however, necessitates the transferring of the refrigerant from the large cylinders to small 5-lb. cylinders used by service men. The transfer of the refrigerant may be done as follows: Invert the large drum in a special stand and connect it to a small drum with a horizontal tubing at least four feet long. Purge this line and then open both valves after placing the small cylinder on a weighing scale. When the small cylinder is charged with the correct amount as indicated on the scales, close the valve on the large cylinder and then carefully heat the line. This will force the liquid out of the line. Next, close the valve on the small cylinder. Never allow the line to become more than warm to the hand.

A charging board is the most accurate means of transferring refrigerant. An important safety precaution needs to be taken. When transferring refrigerant from a storage cylinder to a service cylinder, never fill a service cylinder completely full of liquid refrigerant. This is particularly dangerous in cold weather since liquid refrigerant expands and contracts greatly with a change in temperature. If a service cylinder is filled completely full of cold liquid refrigerant and then brought into a warm room, the liquid tends to expand and the resulting increase in hydrostatic pressure will burst the service cylinder with possible serious consequences.

11-45. DISCHARGING REFRIGERATOR UNIT (REMOVING ALL THE REFRIGERANT)

To discharge a refrigerator, a method is used similar to removing the refrigerant from the condenser and liquid receiver which has been explained previously in this Chapter. It simply consists of fastening an empty or a partially empty refrigerant cylinder to the gauge opening of the discharge service valve and turning the discharge service valve all the way in to close the discharge line. Test for leaks. The compressor is then started which pumps the refrigerant into the cylinder instead of into the condenser. This operation is speeded up by keeping the cylinder partly submerged in cool water, because the gases must condense in the cylinder in order that the refrigerant be pumped out. Do not let the unit pump oil as this will make the refrigerant unusable.

Another method is to attach the cylinder line to the discharge service valve and then heat the unit until the refrigerant has evaporated from the unit and condensed in the cylinder.

Small quantities of refrigerant are best discarded unless a means of distilling is available.

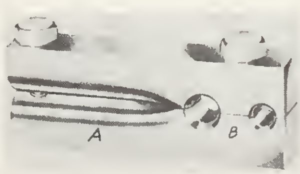
11-46. CARE OF SERVICE VALVES

Practically all service valves are equipped with steel stems, which have a tendency to rust and stick in the valve gland. A very good method of preventing this corrosion is to fill the valve body with refrigerant oil before replacing the plug each time the service valve is used. This oil, of course, should be the specified refrigerant oil for that machine. This precaution is especially recommended for moist, damp locations.

Before turning the valve stem to any position it is always advisable first to

loosen the packing nut that is used as a seal around it. This can be done by loosening the large packing nut a half turn or so. When turning the valve stem it is always best that a very steady pressure be applied to the wrench and that the wrench fit the stem well. If a sudden, jerky motion is used, or if the palm of the hand is used to strike the wrench turning the valve stem, there is a likelihood that the stem will be twisted off, necessitating replacing the service valve.

In case a service valve is "frozen," or stuck, it may be loosened by heating the body of the valve and tapping on the valve stem.



11-28. A pinch-off tool for closing refrigerant lines in cases of emergency or if the service valves are broken. A. For pinching the tubing; B. For reopening the tubing. (Duro Metal Products Co.)

When cracking the valve, always use a fixed wrench, that is, not a ratchet wrench; this is so the valve may be quickly closed again if desired.

Occasionally a service valve will be found in such bad condition as to be useless. In this case, one can close off the flow of refrigerant with a finish off tool, replace the valve, and then remove the finish from the line with the same tool, Fig. 11-28.

11-47. ADDING OIL TO SYSTEM

When a compressor runs too warm or is noisy and it is determined that it is due to a lack of refrigerant oil, there are several methods used to add oil. The most rapid method is to attach tubing equipped with a hand valve to the low side, that is, to the suction service valve, and after purging the tubing immerse it in a glass (clean, dry) jar nearly filled with refrigerant oil. Then run the compressor, and after drawing a vacuum on the low side by turning the suction service valve all the way in, crack the tubing hand valve; the oil will be drawn into the crankcase. Fig. 11-12. It is very important that some of the oil in the glass container be left in the container so the filling tube is always immersed in the oil, otherwise air will be drawn into the system and cause trouble. The reason a glass container is used is to enable the service man to observe how much oil has been added to the unit. It is a safe policy never to add more than a quarter of a pint of oil at a time to the smaller units. If a gauge manifold is used, the tube feed line will not need a hand valve.

Another method of adding oil to the system is to evacuate the crankcase; then equalize the pressures, remove the oil plug of the crankcase housing, and add the oil. Replace the oil plug and evacuate the compressor to the air or into a lye solution (if it is an SO_2 system) until all the air that may have seeped in is removed.

The oil can also be forced into the system by putting the oil in a service cylinder first (draw in by using an evacuated cylinder.) Then build up a pressure in the cylinder with refrigerant gas through the gauge manifold. Invert the cylinder and by using the low side valves the oil can be forced into the compressor.

It is important that all parts in a refrigerating system be absolutely clean prior to installation in the system. One should never breathe fumes of any kind. Do not neglect the use of the gas mask when working in any refrigerant laden atmosphere. This safety device applies to cleansing bath fumes, soldering fumes, brazing fumes, welding fumes, and the like. It is true

that one's body can and will dissipate certain amounts of strange chemicals and fumes but some chemicals and fumes accumulate in the body and there may be an effect not felt for years. GOOD VENTILATION IS OF VITAL IMPORTANCE.

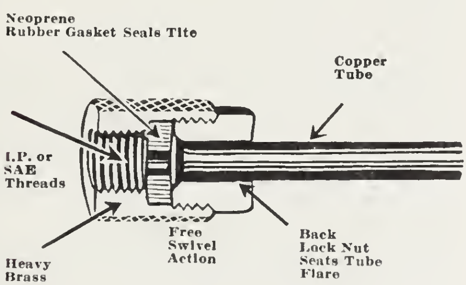
11-48. CLEANING PARTS

Many means have been used to clean parts of a refrigerator. Each method has its advantages. The cleaner should be a good moisture absorber, it should clean off oil and grease, it should be non-toxic, non-flammable and it should evaporate quickly.

Carbon tetrachloride is an excellent cleaner but is dangerously toxic. Therefore, it must always be used in such a way that people will never breathe its fumes. Even breathing small quantities of vapors may accumulate in the body and cause illnesses.

Hand wire brushes, power wire brushes are excellent ways to remove scale and crusted dirt, but grease and oil should be removed first.

Mineral spirits, a kerosene like liquid has excellent cleaning qualities but it is quite flammable. It must always be used in a well ventilated place.



11-29. Speed coupling used on charging and purging lines. A synthetic rubber gasket produces a leak proof joint when the connection is tightened. (Wabash Corp.)

It should be used in small quantities away from any source of ignition such as flames, electrical sparks, friction sparks, and the like. It must be kept in sealed containers and in containers that will automatically close in case of a fire, Paragraph 12-26.

11-49. MISCELLANEOUS SERVICE NOTES

Pinching lines is a practice to be used in cases of emergency only. Many service men follow this practice needlessly and it only leads to future trouble. Almost all the systems are provided with sufficient valves to service them. One must remember that adding refrigerant to a system means that some of the oil in the system will be dissolved in the refrigerant; if a unit becomes noisy soon after the refrigerant has been added, some refrigerant oil should be added. Electric motors, when installed, should have soldered leads; the motor must be very carefully aligned with the compressor, and the belt tightness should be just right.

11-50. LOCATING TROUBLES

The methods of testing used to locate the sources of trouble are all based on the operating principles of the mechanism. By checking the pressures, the temperatures, the running time, etc., one is soon able to isolate or pick out that part of the system which is giving trouble.

Naturally the service man must have a thorough knowledge of the fundamentals of refrigeration and of the cycles before he can become a reliable and competent trouble tracer and repairer. It is obvious that one must locate the trouble in a refrigerator mechanism before dismantling it in order to keep the cost of servicing at a minimum and to make sure that the repair work is going to enable proper functioning of the mechanism after assembly.

The methods of locating troubles naturally vary with the type of the sys-

tem, that is, with the direct expansion, with the low side float, with the high side float or with the capillary tube. The call for service should give the first indication of what the trouble will be; the owner will probably say that there is an odor, that it costs too much to operate it, that it is not freezing but is running continuously, or it is freezing but running continuously, etc. From these trouble calls the service man may usually get a pointer as to what the trouble is, but he should always verify these statements by checking over the refrigerator before attempting any trouble shooting or service work.

The method of trouble tracing is best learned and is best adapted to practical work by first classifying the type of service call and then determining what caused the trouble named in the service call. Therefore, the following trouble shooting pointers have been prepared to help the service man. Naturally, it is impossible to give every detail, but once the service man learns the method of trouble tracing he should have no difficulty.

A service man should check all of the following things in a refrigerating mechanism before coming to a conclusion as to the trouble.

1. The low side pressure
2. The high side pressure
3. The temperature of the cooling unit
4. The temperatures of the liquid line and of the suction line
5. The sound of the refrigerant control (float valve or expansion valve)
6. The running time of the mechanism
7. The probability of leaks
8. Noise.

There are several basic fundamentals that help make locating trouble easier. When there is poor refrigeration, or no refrigeration, either one or both of two things can be wrong:

1. There is no refrigerant, or very little refrigerant.
2. The pump is not moving the refrigerant.

If there is no refrigerant, there will be no liquid refrigerant in the cooling unit. A lack of refrigerant means that the refrigerant has leaked out, or it is being held in a certain part of the system by clogged needles, clogged screens, pinched lines, etc. This clogging condition will cause a high vacuum reading on the low side. If there is a lack of refrigerant there will be a hissing sound at the refrigerant control which will indicate the refrigerant passages are not closed.

A hissing sound at the refrigerant control always indicates a lack of refrigerant because the dry gas going through the restriction will cause the gas noise.

If the pump is not functioning, the low side pressure will be above normal and the condenser and discharge line from the compressor will be below normal temperature.

11-51. LITTLE OR NO REFRIGERATION AND UNIT RUNS CONTINUOUSLY

A. Direct Expansion System

If the unit has lost all the refrigerant, there is naturally no refrigeration; to test for this, install the gauges and determine the evaporating or low side pressure. If this pressure is correct, the only possible trouble is that the unit has little or no refrigerant. If the compound gauge indicates a high vacuum, 20 inches or more, it means that the expansion valve is either so adjusted that it draws this vacuum it is frozen closed, or it has a clogged screen.

A clogged unit can be caused by moisture freezing at the refrigerant control and stopping the flow of re-

frigerant. The results are the same as a stuck closed needle or a clogged screen except that after the system warms above 32 F. at the valve this ice will melt, and normal refrigeration starts again. The only sure cure for the moisture condition is to remove the moisture with a desiccant or dryer. If one suspects that moisture in the valve has caused the clogging, heat the valve with a torch.

This moisture problem occurs with all refrigerants that do not chemically combine with the water, as for example: the Freons, methyl chloride, etc. A high vacuum may also be caused by a suction service valve being shut off or by a clogged or restricted suction line fitting. In either case it is not allowing refrigerant to flow through it, and there will be no refrigerant on the low side which naturally gives continuous running with little or no refrigeration on a temperature controlled unit. This trouble will not be encountered on a pressure-controlled unit.

If the compound pressure gauge shows a high pressure on the low side, that is, a pressure which will not allow the refrigerant to evaporate at a low temperature, the trouble may be a stuck-open expansion valve or one that is out of adjustment. This trouble will have an additional indication of a frosted or sweating suction line because it simply means that the refrigerant is going into the low side too fast and the liquid will flood both the cooling unit and the suction line. This high pressure may also be due to an inefficient compressor. Of course, this trouble may also be due to a broken belt or a sheared flywheel key, but these will naturally be detected on the first inspection of the unit. If the expansion valve is stuck open, it may be due to dirt on the needle. To remedy, one may flush the valve by turning the adjusting screw in and then alternately opening and closing the liquid receiver service valve, causing surges of liquid past the expansion valve needle, thereby cleaning it.

B. The Low Pressure Side Float System (Flooded).

If the compound gauge indicates a high vacuum, it may be due either to a frozen closed needle valve, or to a restricted suction or liquid line (clogged screen). To determine whether it is a frozen needle valve or a lack of refrigerant:

1. Stop the compressor after installing the gauges and notice the action of the compound gauge. If it creeps up very rapidly to almost the pressure on the high pressure side, it indicates that the needle valve is open; therefore, there is a lack of refrigerant; but if the pressures do not tend to equalize, it means that the needle valve is stuck closed or that the suction line or liquid line has become clogged. The valve will also have a steady hissing sound while the unit is running.

If the needle is stuck closed, a sudden jar may loosen it. Use a rubber hammer or shake the cooling unit.

In case there is a lack of refrigerant put back into the system enough refrigerant until the hissing sound stops and the head pressure is normal.

2. If the compound gauge indicates a high pressure, it may be due to a slight lack of refrigerant, a stuck-open needle valve, or an inefficient compressor.

It is best first to eliminate the compressor by testing its efficiency and then determine whether there is a stuck-open needle valve or a lack of refrigerant. To do this, flush the needle valve by shutting off the liquid receiver service valve and running the unit for a few minutes. Then open the liquid receiver service valve very rapidly. Allow a rapid flow of refrigerant through the needle valve orifice which may wash out any dirt particles on the needle

valve seat. If this does not cure the trouble, charge the refrigerator with some refrigerant and see if that will cure the trouble. If this does not, it means that the cooling unit must be dismantled.

A rather accurate check as to whether it is a lack of refrigerant or a stuck-open needle valve is the frosting of the suction line. If the line frosts back excessively it means that there is liquid refrigerant in the suction line caused by too much refrigerant in the cooling unit, as the result of a leaky needle, etc. If the suction pressure is too high, this indicates an open needle valve. To check for an open needle valve the compound gauge will creep up rapidly as soon as the unit is stopped because the high pressure tends to equalize rapidly through the needle valve. A lack of refrigerant will not frost the suction line. Both of these troubles will give a continuous hissing sound in the cooling unit although the lack of refrigerant sound is at a higher pitch. Of course, this may also mean an inefficient compressor, but that is easily checked.

A lack of refrigerant in most systems using low side floats, high side float, or expansion valves, causes the refrigerant to go through the liquid line before it has completely condensed. This gas is therefore warm and one can detect this condition by feeling the liquid line. If the line is warmer than room temperature, a lack of refrigerant is indicated (air cooled systems only).

Short cycling of the mechanism, that is, the unit shutting down for only a minute or two at a time is indicative of a rapid pressure rise in the low side. This is particularly true on the older units which use a pressure control.

C. High Pressure Side Float (Flooded).

If the compound gauge indicates a very low pressure, it means a lack of refrigerant or a stuck-shut float valve. The lack of refrigerant may be checked by watching the pressure gauge pressure when the unit shuts down, for if the high pressure reading is below normal it means that there is a lack of refrigerant; but if the pressure gauge maintains a standard pressure for room temperature it means that the valve is stuck-shut. Another test is to shake the float chamber and if it is a stuck-shut needle, this shaking may break it loose. A clogged screen will also give the above results. If the compound gauge indicates a high evaporator pressure, it is due to a leaky float valve or an inefficient compressor. The compressor may be easily checked for inefficiency. A high head pressure will indicate air in the system or restricted cooling, whereas a lack of refrigerant will give a head pressure below normal. A high side float system must be purged occasionally because a high head pressure, due to air in the system, hinders correct operation of the float. The head pressure of the unit may be easily checked as follows: for an air-cooled unit the refrigerant will be 30 F.-35 F. warmer than the room if the compressor is pumping. By using the refrigerant chart the correct pressure may be determined.

An excessively high head pressure may cause the high side float to collapse. This causes the float to lose its buoyancy and the high side float needle will tend to remain closed at all times. Such a trouble will be indicated by too low a low side pressure and a complete lack of refrigeration.

D. Capillary Tube

If the capillary tube is partially clogged, completely clogged, if there is moisture frozen in the tube, or if the screen is clogged, no refrigerant

can pass into the cooling coil. This stoppage of flow will give a high vacuum reading and a normal or high head pressure. If it is a lack of refrigerant, the capillary tube will be noisy and the low and high side pressures will be below normal.

An inefficient pump will be indicated by an above-normal low side pressure and a normal or below-normal head pressure.

11-52. NO REFRIGERATION; UNIT DOES NOT RUN

The first trouble, and probably the most frequent one, is a blown fuse somewhere in the circuit, which may be easily checked with a trouble lamp and repaired by inserting a new fuse. Also, the power may be shut off, which may be easily checked by using a trouble light; or the motor may be burned out. An ineffective temperature control, such as a leaky power element, which may be checked as described in Chapter 5, is also a cause of the motor not starting. The manual switch on the temperature control may be in the off position or the overload circuit breaker may be in the off position. On those units using a low pressure control for the motor, the trouble may be due to a stuck-shut needle valve in the refrigerant circuit which would naturally draw a very high vacuum on the suction side. This pressure will not creep up again as it would normally, due to a lack of refrigerant in the low pressure side of the system causing the pressure control to keep the electric motor disconnected continuously.

11-53. MOTOR RUNNING CONTINUOUSLY AND NORMAL OR TOO MUCH REFRIGERATION

This trouble is due, usually, to a faulty temperature motor control which will not cut out at the correct temperature. It must be remembered that there is a correlation between the temperature control cut-out point and the evaporating pressure on the low side. If the temperature control is adjusted to cut out at a temperature corresponding to a pressure lower than the evaporating pressure, the thermostat cannot stop the electric motor.

A. Direct Expansion System.

If there is an undercharge of refrigerant in the system there may be just enough to fill the evaporator or cooling unit partially, but not enough to extend to the temperature control cut-out point and shut down the unit. In this way one may get normal refrigeration, but the unit will never shut down. This trouble may be detected by checking the frost accumulations on the exhaust tubing of the cooling unit and seeing if it reaches as far as the temperature control. A shortage of refrigerant is also indicated by a warm liquid receiver and liquid line.

Trouble may also be caused by an overcharge of refrigerant or the presence of air in the condenser, because excessive head pressures decrease the efficiency of the compressor to such an extent that continuous operation is the result.

A leaky expansion valve will sometimes give normal refrigeration, but will not allow the pressure to drop to such an extent that the temperature control will cut out the motor. An improperly adjusted expansion valve will also give this trouble. This will result in a frosted suction line, and an above normal and fluctuating low side pressure.

An inefficient compressor may also be the cause. All these may be checked by the use of gauges. The expansion valve troubles and the compressor

troubles may be checked as mentioned previously.

B. Low Pressure Side Float (Flooded).

An undercharge or overcharge of refrigerant will give the above trouble. An inefficient compressor, excessive head pressure due to air in the system, a restricted condenser, an overcharge of refrigerant, or a suction pressure which is not low enough to cut out the temperature control may give refrigeration but run continuously. This may also be due to a leaky needle valve or lack of refrigerant.

A leaky needle will cause a frost back and it will hiss or gurgle continuously. A lack of refrigerant will hiss continuously, but it will never more than sweat back. Also the liquid line will be warmer than normal in the latter case.

C. High Pressure Side Float (Flooded).

This system is very sensitive to the quantity of refrigerant in the system. Any variation in this quantity will result in faulty refrigeration. Too little refrigerant will result in lack of sufficient liquid refrigerant in the cooling coil and too low suction pressure. Too much refrigerant will result in a flooded unit, a too high suction pressure, and a frosting of the suction line caused by liquid refrigerant. An inefficient compressor will result in insufficient refrigeration.

D. Capillary tube.

In many respects the capillary tube system behaves like the high side float system. If there is too much refrigerant in the system, the excess liquid will collect on the low side and may enter the suction line. This excess may prevent the compressor from producing a low enough pressure to operate the thermostat. Therefore, the unit will run continuously and will produce either a normal refrigeration effect or, more likely it may cause excessive refrigeration. A slight lack of refrigeration will cause only a partially frosted cooling coil and the frosted part may not be close enough to the thermostat to cause it to shut the motor off.

11-54. SHORT CYCLING

By short cycling is meant that the unit runs and then stops every few minutes. This trouble may be due to a rapid pressure rise on the low side of the system caused by a leak at the float valve or expansion valve. This leak will also cause a frosting of the suction line.

Most units are equipped with an overload device in the electrical unit. If the motor becomes too hot or if the motor consumes too much current, these safety devices will stop the motor and then restart it after they cool.

Occasionally, in those systems which use a brine tank, a loss of the brine will cause a short cycle because of the rapid heat interchange. A temperature control which is out of adjustment, that is, one with a very small differential will also cause a short cycle.

If the refrigerator has a pressure motor control, short cycling may be caused by either a leak in the float valve or poorly seated compressor valves. In either case the pressure on the low side will rise rapidly during the off part of the cycle causing the motor to start.

Machines equipped with a high side pressure safety control will sometimes short cycle if the condensing pressure becomes too high because of a high condensing temperature.

11-55. NOISY UNIT

There are three principal sources

of noise: the compressor, the electric motor, and the mounting of the complete condensing unit. A compressor is noisy when the valves, the piston pin, the connecting rod, and piston have become worn or if it pumps oil. Sometimes when the compressor gets very warm, it will develop knocks which are usually rather hard to remedy.

The metal shaft seal used on most of the conventional compressors occasionally becomes very noisy and emits a very shrill squeak. This is indicative of a lack of oil, at the seal, and, if not remedied immediately, will soon score the seal and naturally cause a leak at that point.

The electric motor will give noise trouble due to a fan roar, squeaky bearings, or an armature rumble. Occasionally, if the motor is loaded too much the repulsion start does not cut out and will result in a continuous noisy operation. If this trouble is allowed to continue, the motor will burn out in a very short time.

End play in an electric motor is necessary, but an excess will cause a dull knock.

A belt noise may be due to a very dry belt or pulleys that are out of line. It may be remedied by using soap or some other substance recommended for belts and by lining up the pulleys. Do not use oil. Sometimes the whole machine unit will vibrate excessively, producing a rumbling sound as the unit runs and shaking the cabinet disagreeably. This is due to improper mounting, such as the wrong rubber suspension or spring suspension; it may be due to not enough play in the suction and liquid lines, or some obstruction may have been put in the compartment which destroys the action of the shock and the noise absorbing spring mounting of the condensing unit.

An excessive head pressure will make a unit vibrate more than normal.

A badly worn needle or seat in an expansion valve will sometimes make a chattering noise while the unit is in operation.

11-56. IMPROPER REFRIGERATION BUT UNIT FREEZES ICE CUBES

When the box temperature is over 50 F. and the unit still will form ice cubes, the trouble is either in the excessive frost accumulation on the cooling unit or restricted air circulation in the box. This trouble is also indicative of a poorly insulated box, but this is very seldom the case, due to modern insulation practice.

If there is an excessive frost accumulation on the cooling unit, or if it is a restricted box circulation follow the rules as set forth in Chapter 9. It is possible to crowd the refrigerator cabinet with food and at the same time leave the drip pan below the cooling unit. The box will not operate successfully under these conditions and it is very important that this be thoroughly understood by the owner.

11-57. REVIEW QUESTIONS

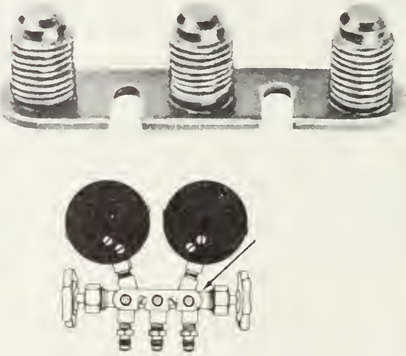
1. What trouble is indicated by a hot liquid line?
2. What is the size of the service valve stem wrench?
3. Why must dry air be used to test the controls for leaks?
4. What does a pounding sound in the compressor, when a vacuum is being produced, indicate?
5. Give several reasons why a gauge installation must be tested for leaks.

6. Why must a leak testing torch be charged and pumped up out in the open air and not in the same room in which a refrigerator is located?
7. What are service valve packings made of?
8. List the procedure followed in lapping an exhaust valve seat.
9. What trouble results in a 110 pounds per square inch head pressure in an air-cooled sulphur dioxide system?
10. A frosted suction line with an excessive low side pressure is the indication of what trouble?
11. In what part of the system is the compound gauge usually installed?
12. In what part of the system is the high pressure gauge usually installed?
13. Why must the pressures be balanced before a system is opened?
14. What should the average low side pressure be for Freon 12, operating at 15 F. coil temperature?
15. What should the average high side pressure be for Freon 12 operating in a room temperature of 85 F.?
16. What precautions should be observed when filling service cylinders with refrigerants?
17. Why may discharge service valves and suction service valves be called two-way valves?
18. What four things cause trouble in an expansion valve?
19. What difficulties may result if moisture is allowed to collect on the outside of the expansion valve bellows?
20. How should a low side float ball be tested for leaks?
21. Explain how to test for sulphur dioxide leaks.
22. Explain how to test for methyl chloride leaks.
23. What indicates the presence of air in a condenser?
24. Name two methods of adding oil to a system.
25. In case the compressor crankcase oil is on the high side, what special precautions must be taken when removing a compressor?

11-58. SERVICE POINTERS

Crankshaft seals are very liable to leak, if the compressor has been idle for a long time. One should turn the compressor over by hand a few times to allow oil to seep between the rubbing metal surfaces. One should also put an ounce of one of the special refrigerant detergent oils into the crankcase to help eliminate this problem.

The high side float system must be carefully charged as an excess of refrigerant causes frost backs while a shortage of refrigerant causes a partially frosted cooling coil.



11-30. A service charging hose holder. This is a time saving device that will protect charging hoses and keep the hoses clean. This device is fastened to the back of the gauge manifold, and the open ends of the three hoses are sealed by threading them on these plugs. (Madden Brass Products Co.)

Chapter 12

THE REFRIGERATOR SERVICE SHOP

Inasmuch as the minute details of all refrigeration work are so important for the safe and satisfactory operation of the refrigeration mechanisms, a careful study must be made of the techniques of performing common operations. Careless, inaccurate, slipshod work has no place in refrigeration. A good service man knows this and is therefore a conscientious and expert workman. It is the aim of this chapter to give the necessary foundation in the use of tools and the use of refrigeration shop equipment required for the successful installation and handling of refrigeration equipment.

12-1. THE SERVICE SHOP

The specialized refrigeration service shop has appeared as a result of a definite need. A typical service shop is that maintained by large, factory-authorized, service organizations, which sell, maintain, service, and repair equipment. They usually comprise a completely equipped repair shop, employing one or two full-time men who repair equipment that is brought in by the service organizations. In most large cities a number of independent service men may be found who are doing refrigeration service work as individuals. These one-man organizations rarely have the equipment or time to overhaul compressors or other parts. Many larger refrigeration service organizations also prefer not to set up an elaborate shop equipment which they are not able to keep operating continuously. Catering to these service organizations, specialized service repair shops may be found which rebuild and repair equipment. They are usually operated by men who are skillful mechanics and who have good equipment. These shops repair the equipment for the independent service men. Such a shop may be termed a wholesale repair establishment, Fig. 12-1.

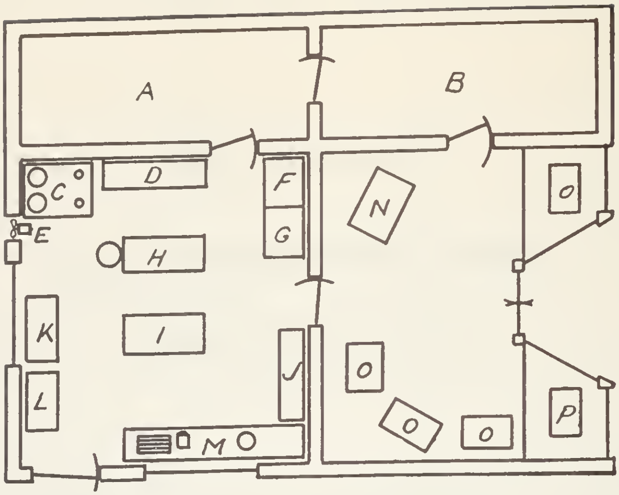
The following paragraphs are meant to offer suggestions concerning the organization and equipment of such a repair shop.

The purpose of the refrigeration service shop is to repair all equipment brought in by the service men and to keep on hand the necessary parts, equipment, and supplies for installing and servicing.

The shop should be centrally located in respect to the distribution of refrigerating equipment in the locality. It should also be provided with shipping facilities and parking space. The shop should have some display space, or window space, to provide an exhibit of supplies, parts, equipment, and services available.

12-2. SHOP EQUIPMENT

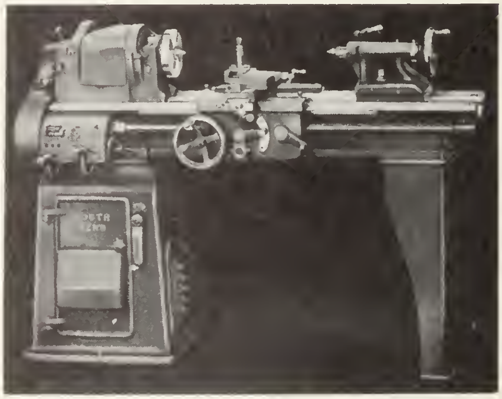
The type of work to be done determines, to a great extent, the equipment



12-1. A typical refrigerator sales and service shop. A stockroom; B. Refrigerator storage room; C. Charging outfit; D. Drying oven; E. Exhaust fan; F. Small parts rack; G. Tool cabinet; H. Tear-down bench and cleansing bath; I. Assembly bench; J. Repair bench; K. Old parts; L. Rebuilt parts; M. Testing bench; N. Office desk; O. Refrigerators; P. Refrigerator unit.

necessary for such a shop. One may choose from the following list of equipment the items necessary to do the work desired. The list is complete enough to enable one to perform almost any manner of service or repair work.

- Lathe
- Arbor Press
- Grinder and buffer
- Air compressor
- Welding equipment
- Lapping blocks
- Charging apparatus
- Compressor testing stand
- Motor testing stand
- Drying oven
- Float control tester
- Expansion valve tester
- Cold bath for thermostatic controls
- Purging equipment
- Oil dispenser
- Storage racks for
    - A. Completed work
    - B. Rebuilt work
    - C. Unfinished work
- Refrigerant distilling apparatus
- Cleaning bath
- Acid dip bath
- Paint spraying booth and equipment
- Assembly bench
- Tear down bench
- Supplies
- Shop tools



12-2. A refrigeration shop lathe. This lathe can be used to do general shop work and it can also be used to cut open hermetic motor-compressor domes.
(South Bend Lathe Works)

12-3. LATHE

A lathe may be used for resurfacing valve plates, for lapping crankshaft seal shoulders, for straightening crankshafts, for turning motor armature commutators, for refacing motor bearings, for straightening armature shafts, for winding tubing, for opening water-cooled liquid receivers, and for doing many other things. The lathe should be a screw-cutting type with at least a 24-inch bed and a 9-inch swing, Figure 12-2. It should be provided with a grinding attachment to make grinding

crankshaft shoulders possible. It should have a large face plate for mounting hermetic domes. It should also be equipped with a steady rest for keeping liquid receivers true when cutting them open.

12-4. ARBOR PRESS

A mechanical or hydraulic arbor press is needed to install electric motor bearings, compressor bearings, and hermetic dome stators. Many fixtures will be needed to permit full use of the arbor press. These fixtures should be mounted on a board near the arbor press for easy accessibility.

12-5. GRINDER AND BUFFER

An electric grinder and buffer combination may be used for conditioning shop tools and for cleaning and polishing the various brass parts of a refrigerating mechanism. A fine buffing wheel can be used to clean steel and cast iron parts such as gasket surfaces, etc.

All rebuilt units have a much neater appearance if the brass work is given a polish. A machine equipped with its own stand is to be preferred; also a ball-bearing motor, having a built-in switch is desirable.

12-6. AIR COMPRESSOR

An air compressor is valuable in the shop for many purposes: air pressure is needed to test different parts of the refrigeratingsystem upon assembly, and to furnish compressed air for the city gas and air torches. Air is also needed for blowing out screens and other parts of the refrigerating system when cleaning them. A dehydrator should be mounted in the suction line of the compressor to assure that the air which is delivered by the compressor is dry. A moisture trap is needed in the discharged line to receive moisture. The air storage tank should be purged each week. An old refrigerator condensing unit may be used as an air compressor by using a large receiver. A pressure of 125 pounds per square inch to 150 pounds per square inch should be maintained. The intake side of the compressor may be used to evacuate parts when dehydrating, or when a vacuum is needed for testing a mechanism. This compressor may be used to supply air for spray painting if its capacity is adequate. A one horsepower compressor or larger is recommended. Air pressure should never be pressed against one's skin as it may cause air bubbles under the skin. Also use goggles when using air to clean parts.

12-7. EVACUATING EQUIPMENT

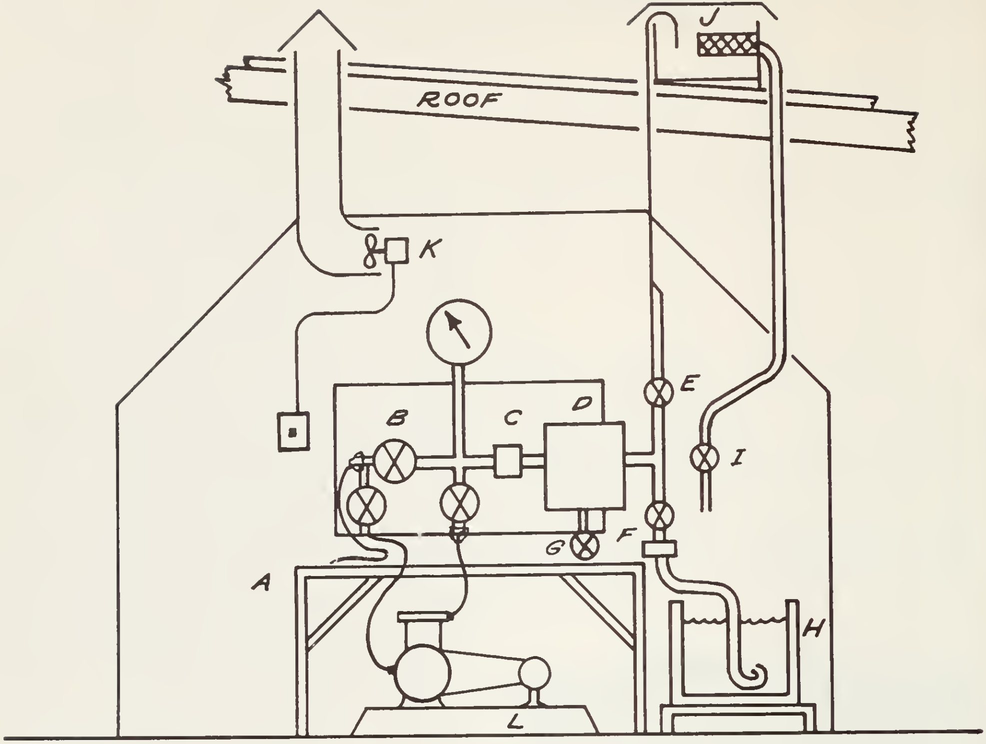
Many refrigeration units are brought into the shop fully charged or partly charged with refrigerant. This refrigerant must be removed from the system before it may be dismantled.

The method of removing the refrigerant varies with the kind of refrigerant and whether or not the refrigerant is to be discarded or saved.

If too much refrigerant is not involved, such as a domestic unit or a small hermetic unit, it is best to discard the refrigerant. However, if it is difficult to replace the refrigerant, or if a large quantity of refrigerant is to be removed from the unit, it should be saved.

When discarding the refrigerant, one must consider whether or not the refrigerant is toxic, irritating, flammable, or if it has a high oil content. Sulphur dioxide, for example, is a toxic refrigerant and it is also irritating.

Basically, the purging apparatus must consist of a securely mounted line (copper tube) leading to the roof of



12-3. An evacuating apparatus. A. Stand, B. Hand valves, C. Check valve, D. Oil trap, E. Purge valve, F. Neutralizer hand valve and check valve, G. Oil trap drain., H. Neutralizer tank, I. Direct purge to roof, J. Oil trap screen, K. Exhaust fan, L. Vacuum pump.

the shop. This line should have a shut off valve, a pressure gauge, a check valve, and a sediment trap. The discharge end of the line should be installed in an open trap to permit slow mixing of the refrigerant with the atmosphere and to catch any oil that may be carried up the purge line, Figure 12-3. It is of great importance that the purging bench be very well ventilated, a three sided enclosure with a hood and equipped with a large volume exhaust fan is needed to prevent any fumes from seeping back into the shop proper.

12-8. WELDING EQUIPMENT (GAS AND AIR)

The gas welding equipment needed consists of an oxygen tank, an acetylene tank, regulators and gauges, hose, and a torch. This equipment will be valuable for soldering, brazing, and welding the various parts of refrigeration systems. It may be used in cases of breakage, or to reassemble liquid receivers after new water-cooling coils have been installed. All welding tanks should be provided with suitable supports in order to eliminate any danger of their being knocked down. The local code on welding should be thoroughly understood if welding equipment is set up and operated. Never operate the welding outfit near the paint booth. CAUTION: Never use oxygen, acetylene, or any other welding fuels, for the purpose of developing a pressure in refrigeration tubing, piping, or equipment. Dry air or carbon dioxide are the only safe substances to use for developing pressures in refrigeration lines. A severe explosion is sure to result if welding gases are used.

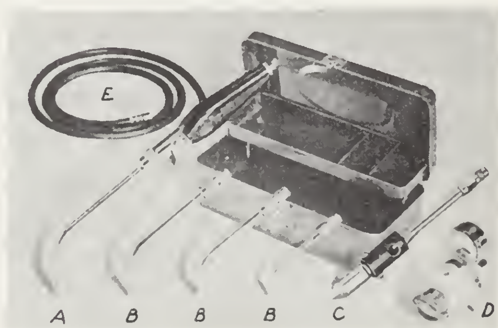
The electric welding equipment may

be either A.C. or D.C. A.C. equipment is the most popular because small units may be purchased. However, do not purchase any equipment that uses 110 Volt feed-in as the equipment can only use 1/16 electrodes efficiently. A unit using 220 Volt feed-in is more practical as it can use 1/8 in. electrodes easily. Steel, copper, cast iron, and aluminum can be welded successfully. CAUTION: The welder should wear an approved arc welding mask and wear gloves. Arc welding is a popular way to reweld hermetic domes.

12-9. SOLDERING EQUIPMENT (GAS AND AIR)

The service man uses the soldering technique for many things. The most popular soldering outfit is the acetylene gas and air torch. These acetylene-air torches furnish a clean flame at a temperature of 2500 F. With compressed air, the torch flame temperature is 2500 F. to 2800 F. The acetylene is supplied in cylinders of 40 cu. ft. capacity and 10 cu. ft. capacity. A 3/16 square valve stem valve is located in the cylinder and a fixed adjustment or variable adjustment regulator is attached to the cylinder valve. A 3/16 in. inside diameter fabric reinforced (red color) hose connects the regulator to the torch. The torch is made of brass and has a wooden handle and is usually equipped with a shut off needle valve. Various size tips are available to screw into the handle and although the flame temperature is the same for each type, the amount of heat is greater as the tip hole or orifice is made larger, Figure 12-4. These torches are used for soldering, silver brazing, brass brazing, etc. They do not produce a high enough temperature to do successful welding. It is important to follow the following safety precautions:

1. Always use the acetylene at a pressure of 15 lbs. per sq. in. or less as higher pressure may cause an explosion due to the instability of the acetylene at higher pressures.
2. Always use the cylinder in a vertical position because the cylinder has a porous filler wet with acetone in which the acetylene is dissolved. If the cylinder is laying down while in use, some acetone may flow out, causing a dirty flame and the acetone may grease up the regulator and valves.
3. Keep the flame away from any flammable substance such as oil, wood, paper, paint, cleansing fluids, methyl chloride, any barrels, or cylinders which may have contained flammable material at one time. Use an asbestos sheet or board to protect surfaces that should not be discolored or scorched when using the torch.
4. Always light the torch with a flint lighter, as matches or a cigarette lighter may bring your hand too close to the flame. Also, the dropped match or lighter may cause a fire. A very clever torch now on the market is a torch with



12-4. An acetylene-air soldering and brazing apparatus. A. Large tip and handle, B. Smaller tips, C. Soldering tip, D. Pressure regulator, E. Hose to connect torch to regulator.
(Linde Air Products Co.)

a built-in flint lighter and a spring valve that automatically closes when the torch is dropped or laid aside.

12-10. LAPPING BLOCKS

Lapping blocks are used to resurface accurately sylphon seal rings, valve plates, switch contact points, and valve disks. These blocks may be constructed of plate glass. Sandpaper blocks may be accurate enough for switch contact points.

Plate glass lapping surfaces, using oil and a very fine grinding compound, should be used for sylphon seal rings. Chapter 11. It is difficult for a beginner to lap a surface accurately. One should use very little lapping compound, but considerable oil; the work should be moved in a figure eight motion over the block surface. The article that is being lapped should be held between the thumb and the index finger only; as the lapping process advances, the article should be turned in the fingers to compensate for any uneven pressure that may be applied. One should use the entire lapping surface of the block evenly; otherwise low spots will be worn into the block and accurate work cannot be produced. A lapping block may be kept accurate by occasionally lapping it on another lapping surface. This will tend to wear away the high spots on both the blocks. However, for most accurate lapping, three blocks should be used and these blocks periodically lapped against each other.

After the blocks have been used, they should be thoroughly cleaned, be given a clean oil film, and then covered with a wood or plastic cover to protect the surface from dust and abuse.

12-11. CHARGING APPARATUS (SINGLE STATION)

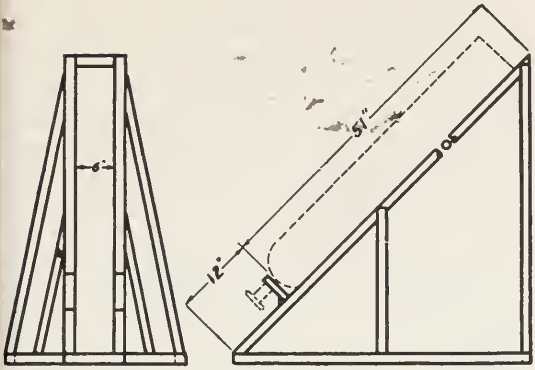
Three types of charging apparatus may be used.

The simplest type consists of a stand on which a 150-pound refrigerant drum, or cylinder, may be mounted in an inverted position. This stand must be so constructed that the cylinder valve is easily accessible, Figure 12-5. A 1/4" charging line should run from the storage cylinder to the service cylinder as shown in Figure 12-6. This charging line may or may not have a purging line tapped into it. It should be approximately horizontal and at least 4 feet long. By carefully heating the storage cylinder slightly, or preferably by cooling the service cylinder, the refrigerant may be easily transferred. The amount of refrigerant transferred may be determined by placing the service cylinder on a weighing scale during the charging operation. The charging line must be thoroughly purged before allowing the refrigerant to pass through it into the service cylinder. The purpose of the auxiliary line, which is connected to the main charging line through a valve, is to permit the purging of the small cylinder into some receptacle or outdoors. This thorough purging decreases the pressure in the service cylinder in addition to removing the air from the line, which allows charging the service cylinder without heating or cooling either cylinder. When connecting the service cylinder to the storage cylinder, proceed as follows:

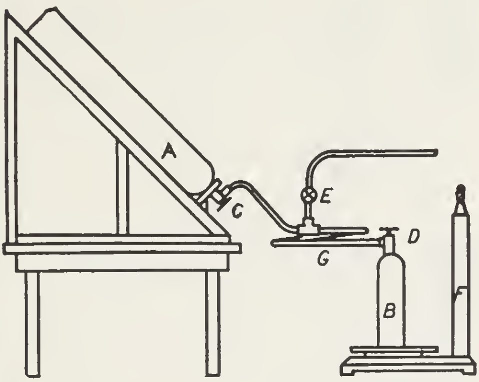
ALWAYS WEAR GOGGLES WHEN WORKING ON PRESSURIZED APPARATUS!

1. Place the service cylinder (B) in a non-tilting stand on the weighing scale (F).
2. Connect the charging line (G) to the service cylinder (B) but leave the connection loose at the service cylinder.
3. Crack the storage cylinder valve (C) very slightly and when some refrigerant is noticed escaping at the service cylinder connec-

tion, quickly tighten this connection.



12-5. A metal stand used for holding large refrigerant cylinders to facilitate transferring the refrigerants.



12-6. Set up for transferring refrigerants from a storage cylinder to a service cylinder and weighing. A. Storage cylinder; B. Service cylinder; C. Storage cylinder valve; D. Service cylinder valve; E. Purging or evacuating valve; F. Weighing scale; G. Horizontal tubing loop.

4. Note the reading of the weighing scale, then open the valves. After the correct weight of refrigerant has passed into the service cylinder close the storage cylinder valve.
5. Now carefully warm the charging line to force the liquid remaining in it in to the service cylinder. Use the heat from one's hand or use an electrical heating element.
6. Close the service cylinder valve and disconnect the line. Plug or cap all connections immediately.

12-12. CHARGING APPARATUS (MULTIPLE STATION)

This system may be used the same as the previous system but it has a vacuum pump connected to the charging line. The exhaust from the vacuum pump is piped to the outdoors through a check valve. The vacuum pump is connected to evacuate both the charging line and the service cylinder.

After the charging lines and the cylinder have been evacuated, shut off the vacuum line valve and turn off the vacuum pump. Now open the storage cylinder valve and the pressure difference will cause liquid refrigerant to flow into the service cylinder until it has become filled with the proper weight of refrigerant.

Shut off both cylinder valves. Open the vacuum line valve and start the vacuum pump. This action will remove the refrigerant from the charging line.

A gauge mounted in the charging line will inform one at all times what pressures are present in the lines.

12-13. REFRIGERANT CHARGING APPARATUS (VACUUM PUMP AND REFRIGERATION)

A Refrigerant Charging Apparatus using a Vacuum Pump and a Cooling Coil is shown in Fig. 12-7.

This popular method of transferring refrigerants cools the refrigerant to maintain a good pressure differential between the storage cylinder and the service cylinder. The principle of operation is simple. Because the refrigerants are volatile which means they evaporate and condense very readily and their pressures quickly react to temperature changes, the flow of the refrigerant from the warm storage cylinder can be greatly speeded if the

refrigerant going into the service cylinder can be kept cool. This cooling may be done by inserting a cooling coil into the charging line (B). If this cooling unit is kept at 40 F. and as the cooled refrigerant flows into the service cylinder (D), the pressure in this cylinder is constantly kept at a lower pressure than the pressure in cylinder A. To operate this system proceed as follows:

(1) Connect the flexible charging to the service cylinder D.

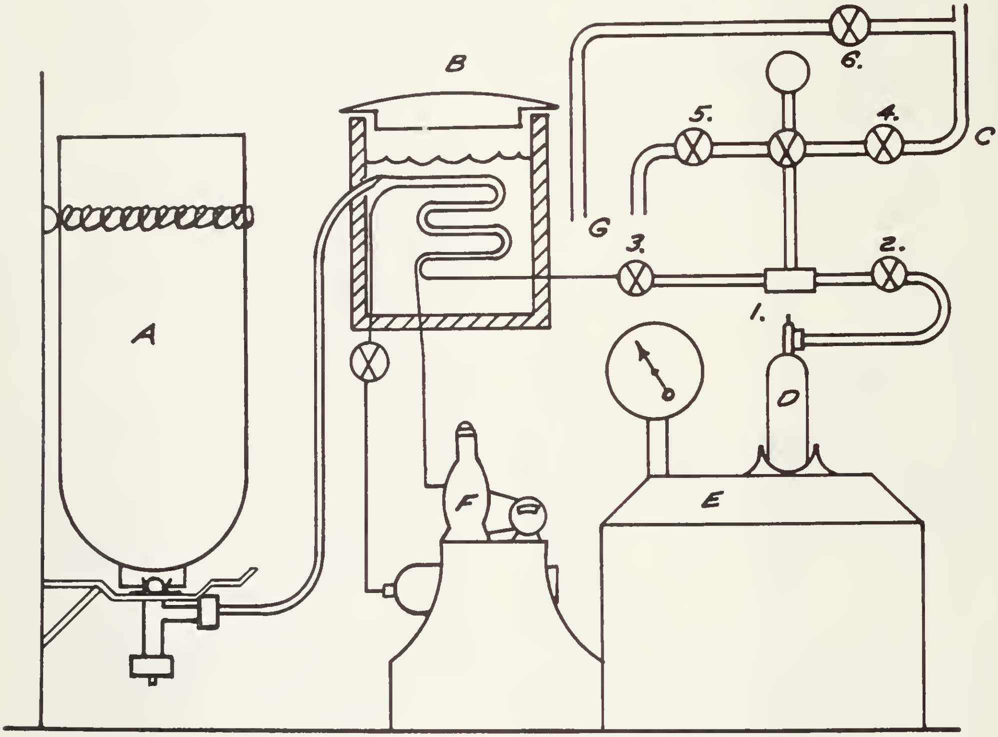
(2) Purge the cylinder by opening valves 3 and 4.

(3) If a vacuum is desired in the service cylinder, close valve 3 and open valves 1, 2 and 5 and operate the vacuum pump until the desired vacuum has been reached, stop the vacuum pump 4.

(4) Close valves 1 and 2 and then open valve 4 and start the refrigerating mechanism. Open valve 4 and the pressure in the storage cylinder A will now push the cooled refrigerant in the cooling coil C into the service cylinder D. As this cooled refrigerant passes into cylinder D, it keeps the cylinder cool and therefore the pressure is low.

(5) By watching the scale E, the amount of refrigerant charged into cylinder D can be easily determined.

Caution: NEVER FILL THE CYL-



12-7. A refrigerant charging apparatus using a vacuum pump and a cooling coil. A. Storage cylinder; B. Cooling coil; C. Purging line; D. Service cylinder; E. Weighing Scale; F. Refrigeration pump; G. Vacuum pump connections. L. Cylinder valve; 2. Charging panel main valve; 3. Cooling coil shut off valve; 4. Purging valve; 5. Vacuum pump valve; 6. Vacuum pump discharge hand valve.

INDER COMPLETELY FULL OF REFRIGERANT; A COMPLETELY FILLED CYLINDER WILL BURST AS IT WARMS TO ROOM TEMPERATURE

Another charging method is more complicated, but is very convenient when large quantities of refrigerant are to be handled. It eliminates the necessity of weighing the cylinders when charging. The device is called a charging board. It uses an intermediate drum, having a reinforced glass liquid-level indicator built into it. Figure 12-8. The intermediate drum is permanently connected to the 150-pound storage cylinder (A) by means of a copper line and a shut-off valve; it is then filled with the refrigerant. The level of the refrigerant is indicated in the glass sight level gauge (L) which is calibrated in pounds of refrigerant. When a small cylinder is to be charged, the cylinder is attached to the intermediate drum at C and the connecting line is purged. After the cylinder is cooled, the opening of the necessary valves will allow the refrigerant to flow from the intermediate drum to the service cylinder. The amount being charged into the cylinder is indicated by the weight scale mounted on the liquid level gauge.

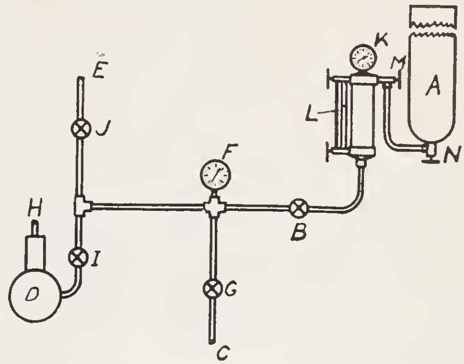
12-14. OIL CHARGING APPARATUS

A shop should have some device to quickly feed oil into compressors or complete units. These oil charging devices should connect to large volume refrigerant oil containers to save on the first cost of oil. This system must be kept exceptionally clean and dry.

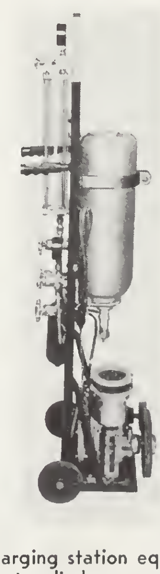
At least two grades of oil are needed in the shop. Oil of 150 Sayboldt vicosity is needed for systems using sulphur dioxide refrigerant while oil of Sayboldt viscosity of 300 is used for Freon 12, Freon 22, and methyl chloride.

Special service devices are on the market which may be used to charge either refrigerant or oil into the condensing unit, Fig. 12-9.

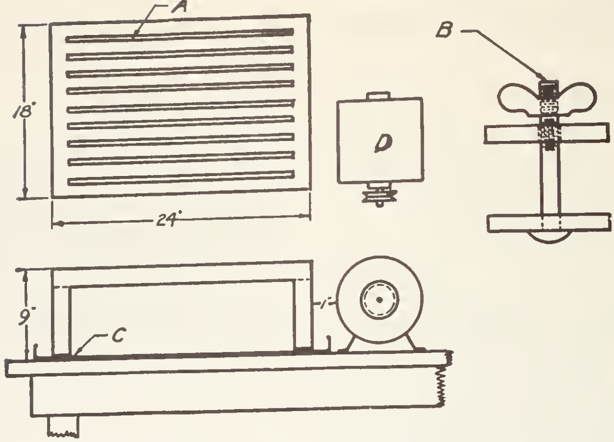
It is to be recommended that the quantity of oil added should conform to the compressor and to the amount of oil recommended by the manufacturer of that unit. Many times this information is not available, especially if



12-8. Method of transferring refrigerant from a storage cylinder to a service cylinder by means of a charging board. A. Storage cylinder; B. Charging control valve; C. Connection to unit or cylinder to be charged; D. Evacuating pump; E. Purging line; F. Compound gauge; G. Disconnecting valve; H. Pump discharge; I. Pump control valve; J. Purge control valve; K. High pressure gauge; L. Liquid level sight gauge; M. Charging cylinder control valve; N. Storage cylinder valve.



12-9. Portable charging station equipped with vacuum pump, a refrigerant cylinder, a graduated glass tube and valves. It can also be used for charging the system with oil.
(Airserco Mfg. Co., Inc.)



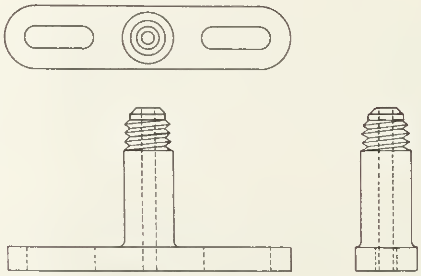
12-10. A compressor testing stand made of 1/4-in. x 1 1/2-in. x 1 1/2-in. welded angle irons. A. 3/8-in. slots; B. 5/16-in. bolt; C. Oil catch pan; D. Electric motor.

working on obsolete models. A generally satisfactory method of charging a compressor with oil that will result in the correct quantity of fresh refrigerant oil of the proper grade is as follows: run the compressor, allowing the oil to be drawn into it, when the compressor starts throwing oil vapor out of its discharge opening, it is an indication that enough oil has been added.

12-15. COMPRESSOR TESTING STAND

Compressors should always be carefully tested after being overhauled and before being put in service. Compressors must be run-in for a number of hours after new bearings have been installed. In order to facilitate and running-in compressors, a compressor test stand should be used. This consists of a steel bench with some flexible means of clamping different size compressors to it. Some test stand tops have grooves which make a very flexible clamping arrangement possible, or the top may be drilled and tapped with a large number of holes in a definite pattern to enable clamping arrangements to be attached. The motor used for driving compressors on test should be 1/2 H.P. or more. Compressors on test must be driven at a speed corresponding to the normal operating speed. This necessitates an arrangement of pulleys whereby various compressor speeds may be obtained, a variety of belt lengths will be found necessary to test various types of compressors, Figure 12-10. If possible all compressors, after being overhauled, should be run in on this stand from 8 to 25 hours before going into service.

They should also be tested thoroughly to determine their operating characteristics. The best test is to determine the quantity of gas the compressor will pump under normally operating low and high side pressure. This is rather difficult to determine because of the elaborate set up of flow



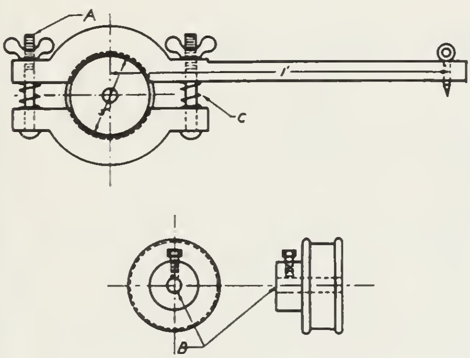
12-11. A universal flange connection.

meters, regulating valves, and other instruments required. The exact method of doing this varies with various manufacturers. No uniform pro-

cedure can be specified here. Most methods depend upon the time required to develop a specified air pressure in a tank of a specified size.

Some compressor test stands use an electric motor drive mounted on a swing base. The weight of the electric motor automatically produces the correct belt tension. The lines for connecting the gauges to the suction opening and the discharge line to the compressor are usually flexible lines and they are connected to the compressor by means of universal flange connections, Figure 12-11.

A fair estimate of a compressor's efficiency may be easily obtained by determining how high a vacuum the compressor can produce when operating against its normal head pressure. The time required for the compressor



12-12. Motor testing torque arm and pulley. A. 5/16-in. wing nut and bolt; B. Reamed holes for various sized shafts; C. Spring.

to draw a high vacuum is also an indication of its pumping ability. If the valves and pistons are in good condition, a compressor should maintain this vacuum after it has stopped.

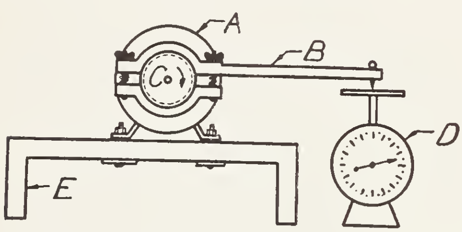
The compressor crankshaft seal may be checked by sealing the low side of the compressor and running the compressor with an 18-inch length of 1/4-inch copper tubing connected to the discharge service valve. The free end of this tubing should be inserted in a bottle, half full of refrigerant oil. While the compressor is pumping the vacuum, bubbles will come out of this tubing. If the bubbles continue to come out of the tubing, they indicate a seal or low side leak. After the highest possible vacuum has been reached, no more bubbles should come out of the tubing. To establish the source of the leak definitely, put oil around the seal as the compressor runs; if the seal is leaking, the oil being sucked into the seal will momentarily stop the leak, and the compressor will cease to pump bubbles. This definitely locates the leak at the seal. A good compressor should be able to produce 22 to 24 inches of vacuum against its normally operating head pressure and maintain it.

A compressor testing stand may also be used to charge a compressor with oil.

12-16. MOTOR TESTING STAND

Electric motors, when in need of repair, are usually taken to a wholesale electric motor repair shop to be overhauled. However, many of the refrigeration service companies prefer to repair as many of these motors as possible. In case re-winding the motor is necessary, this should be done in a shop equipped for this kind of work. In many cases when motors come in, it is a question whether the motor should be repaired or rewound. It is then necessary to test the motor carefully to determine its operating characteristics. To do this, a torque testing stand should be used, Figure. 12-12. This testing stand consists of a stand and a group of pulleys with equal diameters to fit various size motor shafts. The surface of these pulleys is smooth and flat. A torque arm lined with automobile brake lining is arranged to fit the pulleys. The length of the torque arm should be exactly one foot between its point of support on the scales and the

center of the motor pulley. A spring loaded adjustment mechanism should be arranged on the friction surfaces of the torque arm to enable various frictions to be produced between the torque arm and the motor pulley. The extremity of the torque arm is placed either on a spring scale or preferably on a platform scale, Figure 12-13. The torque arm should be balanced to prevent any prior loading of the scale. The torque arm must be level at the time the readings are taken. The torque of the motor can then be very accurately checked for stall condition and full speed load. The torque obtained in this way may then be read directly from the scales in pounds feet. This data, if compared with the manufacturers torque ratings, will indicate the condition of the motor. The switch mechanisms and brush mechanisms of these motors may be checked by using this stand. It

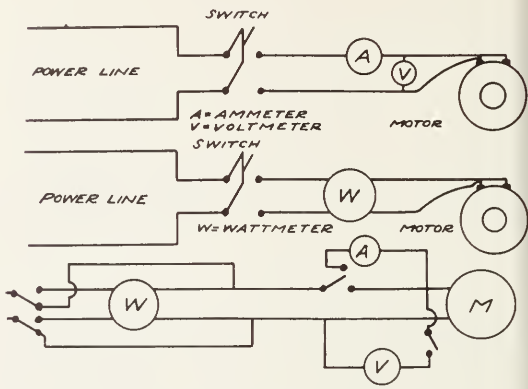


12-13. Showing the use of a complete motor testing torque arm and pulley. A. Motor; B. Torque arm; C. Pulley; D. Weighing scale; E. Stand.

is recommended that ammeters, volt meters, and watt meters be used to determine the current draw of the motor The temperature rise of the bearings should be very carefully noted when testing the motors. A thermometer placed in the bearing oil reservoir is recommended for this purpose. The temperature rise should not exceed 72 F. above the room temperature.

Electric dynamometers are available for measuring the power output of electric motors and they can also motorize the motor to determine its friction losses.

The electric meters should be installed in a panel in such a way that push switches can put an ammeter, a voltmeter, or a wattmeter in the circuit, Fig. 12-14.



12-14. A wiring diagram for connecting: (a) An ammeter and a volt meter to a motor. (b) A watt meter to a motor.

12-17. DRYING OVEN

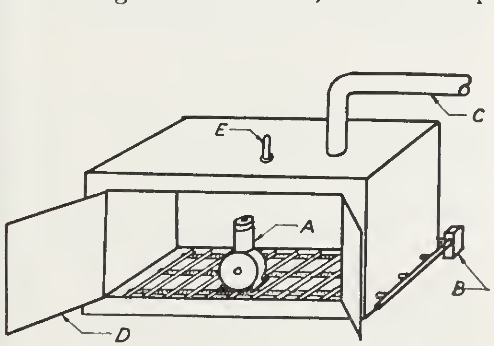
All refrigerating apparatus must be thoroughly dry before being used. Parts become moisture laden while being repaired and should be thoroughly dehydrated after assembly and after they are checked for working ability. This dehydrating may be done in two ways. One way is to place the part to be dried in the drying oven, which is an insulated cabinet using gas burners or electric heating elements, and heating it, Figure 12-15. The part should be maintained at a temperature between 200 F. and 250 F. for 24 hours in order to dry it thoroughly. A better method is to draw a vacuum upon the parts to be dehydrated during this heating period. It has been found that heating periods of 8 hours are long enough if a high vacuum is maintained. Compressors should not be dehydrated with the oil charge in the compressor.

Another method of dehydrating parts consists of producing a vacuum on the part to be dehydrated and then heating

the part with a blow torch for a period of about 15 minutes at 1 hour intervals for at least 4 hours. Do not let the unit become warm enough to be uncomfortable to the hand, particularly parts that are soft soldered. This latter method is only recommended as an emergency. To conserve energy the drying oven floor should be the same height as the shop benches and the benches used to move the compressors should be of this height and fitted with wheels.

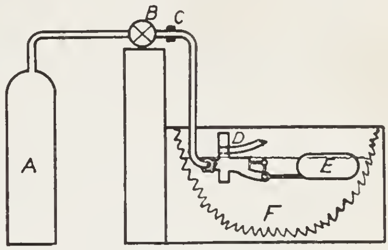
12-18. FLOAT CONTROL TESTER

After a float mechanism has been repaired, it must be calibrated and tested before being installed in a coil. The method of calibrating a float consists of adjusting it until the needle closes with the ball on the center line. To test a float valve for leakage, one of two methods may be used. The liquid line connection to the float valve may be attached to a high pressure, dry air line and the float mounted in such a position that the float presses the needle lightly against its seat. Oil placed around the valve will show the bubbles coming through if the needle is leaking. Sometimes a small leak may be remedied by holding the float valve in such a position that the needle presses against the seat, and then tap



12-15. A gas heated drying oven with an automatic temperature control. A. Compressor; B. Automatic gas control; C. Chimney for exhaust fumes; D. Door; E. Thermometer.

lightly upon the needle with a light hammer. Some companies prefer to check float valves by mounting the float on a special stand; and with the aid of a pulley and weight system, impose a lifting force on the ball, equivalent to the lifting force imposed upon it when it is immersed in the refrigerant. The needle and seat are



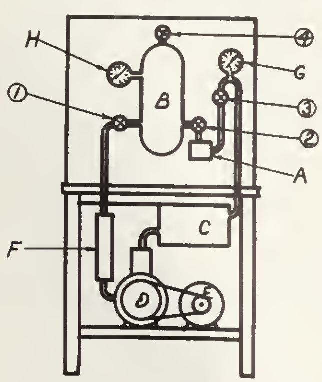
12-16. A low side float valve testing stand. A. Dry air tank; B. Valve; C. Swing joint; D. Float header; E. Float ball; F. Liquid.

then tested for leaks using the dry air line. Other companies use an apparatus whereby the float valve mechanism is lowered into a quantity of liquid after it has been connected to a dry air line. The appearance of bubbles will indicate a leak at the needle, Figure 12-16.

12-19. EXPANSION VALVE TESTER

After an expansion valve has been overhauled, the screen cleaned, the needle and seat repaired, the bellows cleaned, and the anti-freezing solution put in the bellows housing, the expansion valve should be thoroughly tested before being put into service. This test consists of checking the needle, seat, and bellows for leaks under their full pressure range. To test an expansion valve, needle, and seat, one must connect the liquid line fitting to a high pressure dry air line, and the cooling coil connection to a small metal drum. A 6 cubic inch tank is of sufficient size. A very delicate manometer, or pressure gauge, is connected to this

small tank and registers positive pressure and partial vacuums. This drum must also be connected to an air pump in order that a vacuum may be produced on the tank after the expansion valve has been connected to it, Figure 12-17. Turn the expansion valve adjusting screw all the way out and then produce a vacuum on the tank. Allow the expansion valve to remain in this condition for 5 minutes; if the low side pressure rises, the needle or the bellows is leaking. Now turn the expansion valve adjustment in slowly and note the pressure rise with each turn of the adjusting screw. After the screw has been turned in a certain number of turns, a positive pressure will be registered in the tank. This pressure will increase with each turn of the screw to a certain point when the pressure will increase uncontrolled. This point is the critical setting of the valve, and it should be well outside the normally operating pressure ranges of the expansion valve. To test the needle for leaks after the expansion valve has been adjusted to a 5-pound reading, one should wait for 5 or 10 minutes; if the drum pressure does not vary from the 5-pound setting, the expansion valve

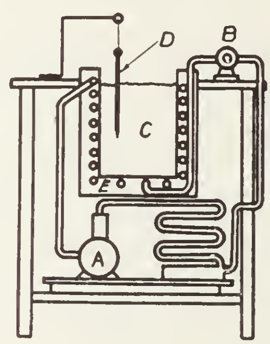


12-17. An expansion valve testing apparatus. 1. Suction line valve; 2. Tank valve; 3. Pressure valve; 4. Pressure release valve; A. Expansion valve; B. Air tank; C. Air storage tank; D. Air compressor; E. Motor; F. Dehydrator; G. High pressure gauge; H. Low pressure gauge.

needle is holding O.K. With a 10-pound pressure registered on the tank gauge, test the bellows for leaks by putting refrigerant oil around the adjusting screw opening. Bubbles appearing here will indicate a leaky bellows.

12-20. COLD BATH FOR THERMOSTATIC CONTROLS

Thermostatic motor controls and thermostatic expansion valves must be adjusted by means of a controlled temperature bath in order to test these controls for operating range and condition. A thermostatic expansion valve should be tested like the expansion valve (Paragraph 12-19), but with the thermostatic bulb placed in an ice water bath or in a refrigerant bath maintained between 30 F. and 32 F. After the



12-18. A cold bath for testing thermostatic expansion valves and motor controls. A. Refrigerating unit; B. Expansion valve; C. Brine bath; D. Thermometer; E. Insulated cooling coil.

expansion valve has adjusted itself to this temperature, it may be tested, using the same process as in Paragraph 12-19. Thermostatic motor controls operate at ranges varying from -20 F. for frozen food cabinets up to temperatures of 45 F. for grocery cabinets, etc. To produce temperatures for testing purposes over these ranges, the best device consists of a small refrigerating apparatus, which uses an automatic expansion valve connected to

a small coil that has been immersed in a brine solution. A thermometer well should be suspended in the brine solution, Figure 12-18. The control bulb of the motor control which is being tested is then immersed in this solution; after a period of 1/2 hour, during which time the bulb temperature has become stabilized, the mechanism may be adjusted to the correct cutting-out temperature, and the control adjusted to snap open the switch at this point. The correct cutting-in point may be obtained by warming the brine, by shutting off the refrigerating unit, by by-passing hot refrigerant into the cooling coil, by adding some hot water, or by using a torch. One must be very careful to do this slowly in order to produce even temperatures.

A device is available that incorporates a refrigerant well, a container for a glass stem thermometer and a place to clamp the thermostat bulb or the thermostatic expansion valve bulb.

12-21. PURGING EQUIPMENT

Often low side float coils, complete condensing units, or complete refrigerators are brought into the shop, and it is necessary to empty them of their refrigerant before working on them. This refrigerant may be saved if provisions are available for storing and redistilling it; otherwise it is best to discard the refrigerant because of the impurities in it. Refrigerants may be irritating and charged with oil; therefore they cannot be discharged directly outdoors. In all cases the oil in the refrigerant should be carefully handled to prevent damage to neighboring property. Sulphur dioxide and ammonia may be discarded by discharging them down a tile or brick sewer drain. Iron pipes should not be used to carry sulphur dioxide refrigerants, while copper tubing should not be used to carry ammonia.

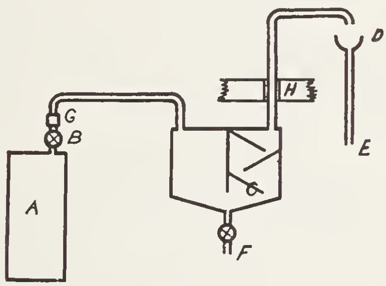
When discarding refrigerants two precautions must be observed. The purging line should be provided with a check valve to prevent the backing up of the refrigerant into the room; a strong flow of water should be run down the sewer while the purging is going on in order to dissolve the refrigerant. Many companies cause their purging lines to run out-of-doors and discard both their oil and their refrigerant out through this line, but trouble has resulted from this system and, if possible, it should not be used. A good system of discarding the refrigerant is to run it through a chemical which will neutralize it.

The purging stand should be hooded, and an out-of-doors exhaust fan should be run from this hood to take away any accidental leaking of refrigerant from the work shop. This fan should be large enough to take care of the ventilation for the complete shop to insure that under practically all circumstances the work in the shop will not be interrupted. The location of the fan should be low, for most refrigerants and their gases formed under room temperature are heavier than air. Some means of taking care of the oil in the refrigerant should be provided as part of the purging stand. This may best be done by means of a tank into the top of which the purging line enters. The purging outlet line then continues from another part of the top of the tank to the outdoors or into the sewer. Between the two openings of the tank, a baffle should be constructed to cause the oil to settle out of the refrigerant gas as it passes through the tank. The bottom of the tank should be provided with a hand valve to enable one to drain the oil periodically. A check valve should be located in the line between the tank and the mechanism which is being purged to prevent the backing up of fumes into the room after the purging

is completed. Figure 12-19.

12-22. OIL DISPENSER

It is more economical to buy refrigerating oil in large quantities, such as in barrel lots. Some means must be provided for dispensing this oil into smaller containers or into refrigerator machines in a manner that will keep it clean and dry. This is best done by



12-19. A diagram of a purging line and oil trap. A. Old refrigerant; B. Valve; C. Oil trap; D. Vent; E. Tile drain; F. Oil drain; G. Check valve; H. Building wall.

a wooden cradle for the barrel to enable mounting it on its side; a faucet may then be screwed into the bung of the barrel. No air openings into the barrel should be provided, but if the oil does not flow out, the sealed opening may be cracked, allowing a little air to flow into the barrel. If an air opening is permanently provided, the oil will absorb too much moisture and may cause trouble in refrigerators in which it is used. A record should be kept of the amount of oil drawn from the barrel in order to know the amount of oil in the barrel at all times. However, the only sure way to have prefectly clean oil, is to obtain it, and dispense it in sealed containers.

12-23. STORAGE RACKS

Separate stands should be provided for completed work, rebuilt work, and unfinished work. These stands may be constructed of either wood or metal. All work that is taken in should be tagged immediately to indicate the owner, the date brought in, and the repairs needed. This card should also contain space for marking the date the work was completed and the time when the unit was put into service. This tag may then be filed for reference. Sometimes the drawers or shelves of these racks are provided with holders for cards rather than tags. The card system permits a much neater record, Figure 12-20.

12-24. DOLLYS AND STANDS

It is necessary to frequently move compressors, condensing units, refrigerators and air conditioners around the shop. They must also be unloaded and loaded on trucks.

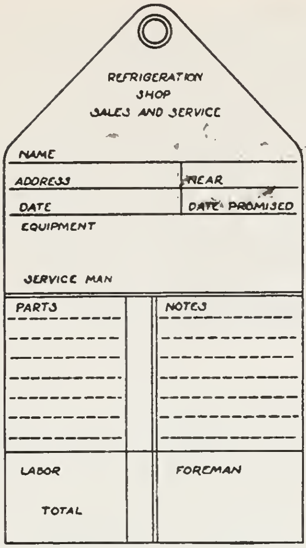
To make this movement as convenient and safe as possible, the shop should have two wheel trucks, four wheel trucks, dollies, lift trucks, etc.

The lift truck or trucks should be motorized to enable one man to pick up the heavy units and load them on trucks, stack them or move the heavy pieces from one place to another.

Sturdy tables equipped with casters made and at the same height as the dehydrating oven height, etc. should be available for transporting refrigeration equipment to various stations in the shop.

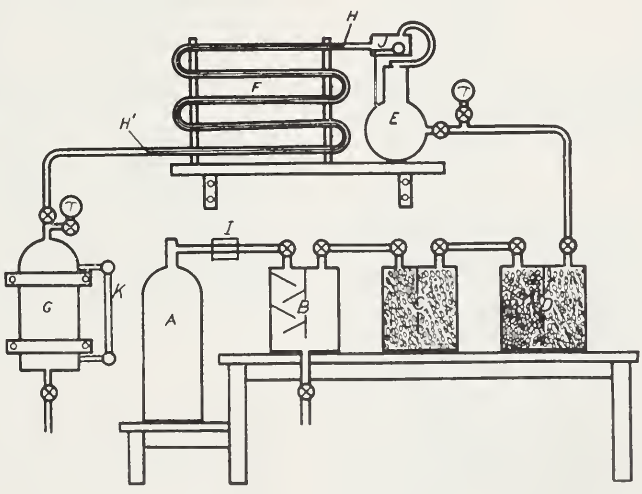
12-25. REFRIGERANT DISTILLING APPARATUS

As previously mentioned, used refrigerants should be discarded because of the oil and impurities dissolved in them. However, if the amount of business warrants it, a distilling apparatus may be used to cleanse, purify, and remove the oil from the refrigerant. A distilling apparatus consists of five main parts: (1) moisture removers in



12-20. A typical refrigerator shop repair card for refrigerator parts.

the form of large calcium chloride, or zinc moss containers, (2) an acid neutralizer consisting of activated alumnia or zinc moss, (3) a vaporizer, (4) a condensing mechanism, and (5) an oil trap. In detail the complete apparatus consists of a refrigerating machine having an extremely large liquid receiver, Fig. 12-21. This machine may have either a water- or an air-cooled condenser; a water-cooled one is preferable. A large oil trap is connected between the compressor and the condenser. The oil separator automatically collects the oil and removes it from the refrigerant. The dehydrator and neutralizer equipment should be installed in the suction line which is then attached to the drum of the refrigerant to be distilled. As the compressor runs, it vaporizes the old refrigerant in the storage drum; when its vapor passes through the drying and neutralizing chemicals, its moisture and acidity is removed. The gas is then compressed and passed through an oil trap which removes practically all the oil vapor from it. From here it passes into the condenser, and upon condensing collects in the liquid receiver, cleansed of its impurities. Some distilling apparatus uses double and triple oil traps and the same number of neutralizers and dehydrators. The neutralizers and dehydrators used must be replaced often in order to keep the chemicals active. A distilling system similar to the above is sometimes constructed, using steam or heating coils for the vaporizing



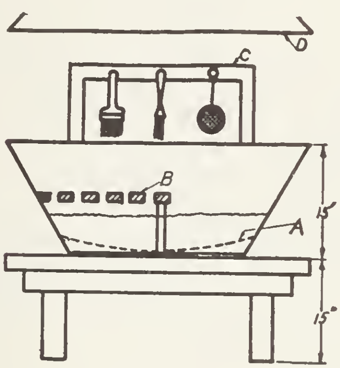
12-21. A cleaning and distilling apparatus for refrigerants. A. Old refrigerant; B. Oil trap; C. Neutralizer; D. Dehydrator; E. Compressor; F. Condenser; G. Storage cylinder; H-H. Water cooling coil; I. Expansion valve; J. Automatic oil trap; K. Liquid level indicator.

means and very cold water for the condensing means.

12-26. CLEANING BATHS

When a refrigerating mechanism is brought into a shop, it should be thoroughly cleaned. The cleaning tank should consist of a large galvanized tank having a fine mesh screen located approximately an inch above the bottom. The tank should be partially filled with cleansing liquid. Paint brushes help clean the parts; a wire brush may also be used, Figure 12-22. A high pressure air jet may be used to clean otherwise inaccessible parts.

After being cleaned, the parts should be rinsed and then placed upon a drying



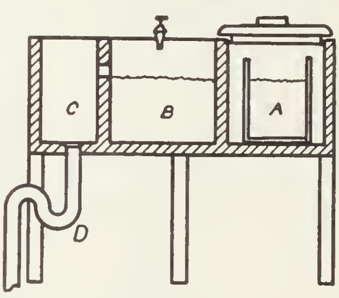
12-22 A cleaning bath and rack for refrigerator parts. A. Screen; B. Wood or metal slats; C. Brush holder and small parts holder; D. Venting hood.

rack located above the bath. Because of the fire hazard, GASOLINE OR NAPTHA SHOULD NEVER BE USED IN CLEANING TANKS. Carbon tetrachloride cleaning tanks should be vented outdoors, as the fumes are very toxic. The fumes are harmful to the kidneys, liver and the brain and the effects are accumulative. NEVER BREATH CARBON TETRACHLORIDE FUMES. A new supply of cleansing liquid should be used every day, or more often, depending upon the amount of work done.

An economical arrangement consists of the use of two tanks. The first tank, containing the dirtier fluid, is used for the first cleaning; and the other tank, which contains clean fluid, is used for the final cleaning and rinsing. It is best to check with the local Fire Department and Industrial Hygiene Department before using a cleaning agent.

12-27. ACID DIP BATH

Many brass parts of the refrigerating system such as fittings, nuts, service valves, etc., become discolored and greasy after a period of use. When such a mechanism is brought into the shop, it is usually desirable to clean it and to make it look like new. A buffing wheel may be used for this purpose, but many crevices and corners are inaccessible to the wheel. A quantity of dilute sulphuric acid in an earthenware crock, which is covered with a wood plate is a very good cleaner for brass parts. Attach the parts to be cleaned to a wire or put them in a perforated earthenware dish; then im-



12-23. An acid dip bath for chemically burnishing brass refrigerator parts. A. Acid; B. Water and soda; C. Drain basin; D. Trap.

merse in the acid for two or three minutes. The operator should wear rubber gloves, apron, and goggles, when using the acid cleaning bath. Brass fittings, cleaned as above, must be immediately rinsed in an earthenware crock full of clean water to wash away

the acid, Figure 12-23. The fittings will now have a very clean appearance. Dilute nitric acid may also be used and it does not have to be heated. However, it is a much stronger acid and therefore more dangerous. Keep acid cleaning crocks under a well ventilated hood to eliminate inhaling of the fumes. These fumes are also very deteriorating and corrosive to practically all metals and the apparatus should have a hood and be vented.

12-28. PAINT SPRAYING BOOTH AND EQUIPMENT

Duco and lacquer paints are often used for finishing refrigerator cabinets and parts. A paint spraying outfit used in a ventilated booth is the best means for repainting these cabinets. The old paint should be removed with paint remover, a scraper and sandpaper. A priming surface should then be applied FOLLOWED WITH AT LEAST TWO coats of the finish paint. For excellent results, each coat should be sanded before the next coat is applied. The painting equipment may also be used for repainting compressors, bases, motors, receivers, etc.

12-29. SUPPLIES

The refrigeration repair shop should have on hand a sufficient quantity of supplies to perform adequately the work encountered. Supplies consisting of the following should be kept on hand:

- Refrigerant
  - Sulphur dioxide
  - Methyl chloride
  - Freon -12
  - Freon -22
- Refrigerant oil
  - 150-162 viscosity
  - 300-350 viscosity
- Tubing
  - 1/4-inch O.D.
  - 3/8-inch O.D.
  - 1/2-inch O.D.
- Fittings
  - Flared
  - Pipe
  - Soldered
- Valves
- Valve Packing Material
- Gasket Material
  - Cleaning fluid
- Paints
  - White for cabinets
  - Black for bases and compressor
  - Thinner
- Cap Screws (cadmium plated or monel)
  - 1/4-inch NF
  - 1/4-inch NC
  - 5/16-inch NF
  - 5/16-inch NC
- Lapping Compound
- Sealing Compound
- Silver Brazing Wire (45% silver)
- Silver Brazing Flux
- Solder 50-50
- Solder Flux (non-corrosive paste)
- Dehydrators and neutralizers
  - Activated alumina
  - Calcium chloride
  - Calcium sulphate
  - Silica gel
  - Zinc moss
- Record tags
- Small Acetylene Cylinders
- Tape
  - Friction
  - Masking
  - Plastic
- Electrical supplies
  - Wiring
  - Conduit
    - Thin wall 3/4-inch and 1-inch
    - Electrical
  - Fuses
    - Cartridge
    - Plug

The quantity of parts and the kind and amount of supplies kept on hand depend upon the type of work specialized in and the amount of work performed. A careful record should be kept

of the amount of stock on hand to insure that a sufficient amount is available to supply all needs.

12-30. SHOP TOOLS

Many common tools are necessary to overhaul refrigerating machines efficiently. Some of the tools commonly used in the refrigerating repair shop are:

A complete set of adjustable reamers for 1/4-inch diameter up to 1 1/2-inch.

Straight and curved tin snips for cutting gasket material.

A set of hollow punches varying in size from 1/4-inch diameter to 3/8-inch for cutting gaskets.

1-quart blow torch for odd heating and soldering jobs.

A halide leak testing torch.

Vises of both the pipe and straight jaw types.

A complete set of socket wrenches equipped with sockets varying from 3/8-inch across flats up to 1 1/2-inch.

Flywheel pullers.

A set of tube benders.

A set of fitting refacers.

Master gauges and thermometers should be used to check the instruments carried by the service men.

A set of adjustable end wrenches varying in size from 6 inches to 12 inches will be found very useful for many different purposes.

A set of pipe wrenches varying in size from 6 inches to 12 inches will also be found to be useful.

A welding station.

36 in. high cart with casters.

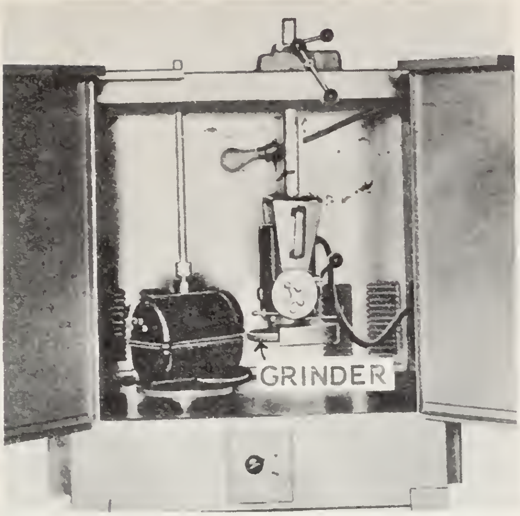
12-31. TOOL RACKS

Probably the most troublesome problem in a shop is to keep the shop tools in their proper place or to know where they are, and who has them

The best system developed to date is to use a tool rack. This rack has a definite place for each tool and a tool check system to indicate who has the tool when it is not on the rack.

12-32. POLICY

A very accurate record should be kept of all work done and the amount spent on each unit for labor and material. Flat rate charges should be made for compressor overhauls, expansion valve overhauls, and for similar work. When work is brought into the shop, it should be marked as to whether it is to be turned out in a definite time, "rushed," or otherwise. The work upon being completed should be reported and recorded in the proper places so that the units will not be lost or misplaced. The work may be guaranteed for thirty to ninety days depending upon the type of work encountered and clientele built up.



12-24. A motor-compressor opener. This special dome welding grinding machine will open a motor-compressor in about twenty minutes.
(Frankell Mfg. Co.)

12-33. COMPRESSOR OPENER

A device used to remove the motor-compressor weld by grinding is shown in Fig. 12-24. The motor-compressor is clamped to a turn table and the grinding wheel grinds the weld as the compressor slowly turns. The wheel automatically adjusts itself to the contour or shape of the weld seam, be it round, elliptical or almost any other shape. The machine will remove both side welds and top welds. The opener mechanism is housed in a steel cabinet provided with two shatterproof windows to enable the operator to watch the grinding operation. Both motors of the unit require single phase, 110 volt power and use about 11 amperes. About two minutes are needed to set up and adjust the machine. The machine then automatically grinds the weld for approximately 20 minutes (timer controlled). One motor is used to operate the turn table while a second motor drives the grinding wheel. The machine may be equipped with either 1/8, 1/4, or 3/4 thickness grinding wheels.

12-34. REVIEW QUESTIONS

The answers to the following questions may be found in Paragraph 12-34.

1. Why must the refrigerants be chemically pure?
2. Why must one be careful when handling most refrigerants?
3. Explain the text, "Never use a cheap refrigerant cylinder."
4. Why is glycerine considered the ideal brine?
5. What are the two kinds of service repair shops?
6. What may a lathe be used for in a repair shop?
7. Describe two types of charging stands used in refrigeration.
8. Why is an air dryer necessary in the inlet of the air compressor?
9. Describe the three kinds of lapping blocks or surfaces.
10. Why must a compressor be run at its rated speed when testing it?
11. What is meant by "baking" a compressor?
12. Why is an exhaust fan located near a charging stand?
13. Why must goggles and rubber aprons be worn when using the acid dip bath?
14. What is the fire hazard in a paint booth? How may it be eliminated?

Chapter 13

THE ABSORPTION SYSTEM

The absorption system differs from the compression system in that it uses heat energy instead of mechanical energy to make a change in the conditions necessary to complete a refrigeration cycle. This system uses gas, kerosene, or an electric heating element as a source of heat supply.

13-1. TYPES OF ABSORPTION SYSTEMS

There are several usable combinations of chemicals that have the property that one may absorb the other without any chemical action taking place. The substance has the property to absorb the other chemical when cool, but will release the chemical when heated. If the substance is a solid, the process is sometimes called adsorbing while if the substance is a liquid, the process is called absorbing.

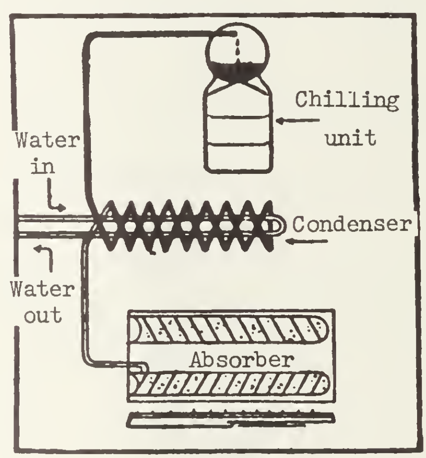
There are two principal types of absorption refrigerators: one utilizing a solid absorbent material, the other using a liquid absorbent. The liquid absorbent machine is the most popular.

These two types of absorption refrigerators are typified by the Faraday, which is a solid absorbent type and by the Electrolux, which uses a liquid absorbent.

13-2. THE ABSORPTION SYSTEM

Fig. 13-1 illustrates a simple absorption system. This diagram is of the solid absorbent type and is produced for the purpose of comparison with mechanical types of refrigerators.

The condensing coil, receiver, and cooling coils are quite similar to those used in the compression system. The compressor, however, has been replaced by a heater or generator. The system does not work so simply as the illustration portrays, but functioning of it may be more easily followed by leaving out the various controls that are explained in detail later.

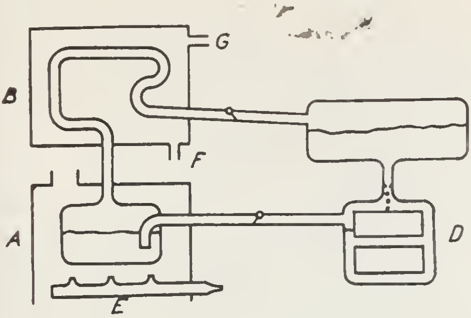


13-1. Elementary solid absorbent cycle.

The most appealing feature of this system is the elimination of moving parts down to a few valves, while cer-

tain domestic applications have moving parts reduced to a minimum.

Fig. 13-2 illustrates a simple absorption system of the liquid absorbent type.



13-2. Elementary liquid absorbent cycle. A. Generator; B. Condenser; C. Receiver; D. Cooling coil; E. Burner; F. Water-in; G. Water-out.

13-3. THE SOLID ABSORPTION SYSTEM

Michael Faraday, in 1824, performed a series of experiments to liquefy certain "fixed" gases -- gases which certain scientists believed could exist only in vapor form. Among them was ammonia, for it had always been regarded as a "fixed" gas. Faraday knew that silver chloride, a white powder, had the peculiar property of absorbing large quantities of ammonia gas. He therefore exposed silver chloride to dry ammonia gas. When the powder had absorbed all of the gas it would take, he sealed the ammonia-silver chloride compound in a test tube which was bent to form an inverted "V." He then heated the end of the tube containing the powder and at the same time cooled the opposite end of the tube with water. The heat released ammonia vapor and drops of colorless liquid soon began to appear in the cool end of the tube. Thus liquid ammonia was produced for the first time.

Faraday continued the heating process until sufficient liquid ammonia had been produced for his purpose. When this was accomplished he extinguished the flame under the powder and proceeded to observe the characteristics of the newly discovered substance.

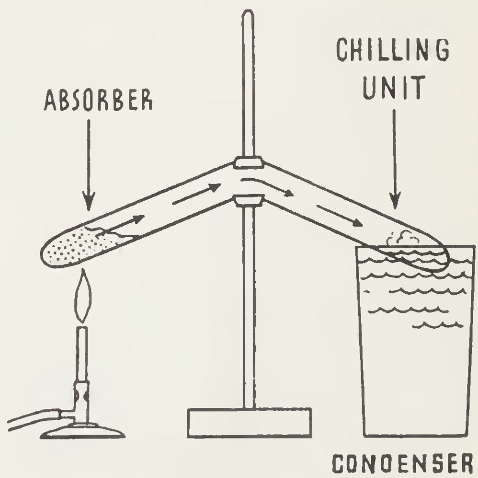
A few moments after the flame had been extinguished, Faraday began to note a most unusual occurrence. The liquid ammonia, instead of remaining quietly in the sealed test tube, began to bubble and then to boil violently. It was rapidly changing back into a vapor, and the vapor was being reabsorbed by the powder. Upon touching the end of the tube containing the boiling liquid, Faraday was astonished to find it intensely cold. Ammonia, in changing from liquid to vapor form, extracted heat and it took this heat from the nearest thing at hand, which was the test tube itself.

The diagram in Fig. 13-3 illustrates the Faraday experiment.

13-4. ABSORPTION SYSTEM CHEMICALS

Several different chemical combinations have been used in absorption units.

Ammonia as the refrigerant and



13-3. Elementary operation of the intermittent absorption cycle.
(Faraday Refrigerator Corp.)

water as the absorbent is the most popular.

High temperature units (air conditioning) are now using water as the refrigerant and lithium bromide or lithium chloride as the absorbent. The pressure in these systems varies between 15 psia in the cooling coil to 1 psia in the condenser.

One company is using methylene chloride as the refrigerant and dimethyl ether of tetraethylene glycol as the absorbent. The pressures are 3psig and 24 in Hg. vacuum.

13-5. TYPICAL SOLID ABSORBENT SYSTEM

From Fig. 13-1 the following elementary cycle may be traced. Heat is applied to the generator or absorber, which will liberate ammonia gas from its absorbent and will increase the pressure to the point where the air or water cooled condenser will remove sufficient heat from the high pressure gaseous ammonia to reduce it to a liquid.

The liquid refrigerant is forced from the condenser to the receiver or storage tank by the pressure of the vápor entering the condenser.

After sufficient ammonia is driven into the condenser and receiver, the heat is discontinued and the generator or absorber cools. When the temperature of the absorber is lowered sufficiently, it begins taking back or reabsorbing the ammonia gas. As the absorber cools it attracts the gas ammonia molecules and as they enter the absorber and are changed to a liquid two things happen. First, the absorber heats up and this heat must be removed. Second, the pressure in the container is reduced to the level where the liquid ammonia can convert again to a gas at such a low heat level that refrigerating temperatures are produced. The apparatus is so constructed that it can obtain this ammonia only from the cooling unit, which necessitates an evaporation taking place there. From elementary physics one knows that this will cause the removal of heat from the cooling unit and its surroundings, and if this cooling unit is located in an insulated box (a refrigerator box) that box will be refrigerated.

As the ammonia evaporates from the cooling unit it is replaced by liquid ammonia from the receiver. This operation continues until the proper amount of ammonia is reabsorbed by the generator, when heat is again applied and ammonia is again moved to the receiver.

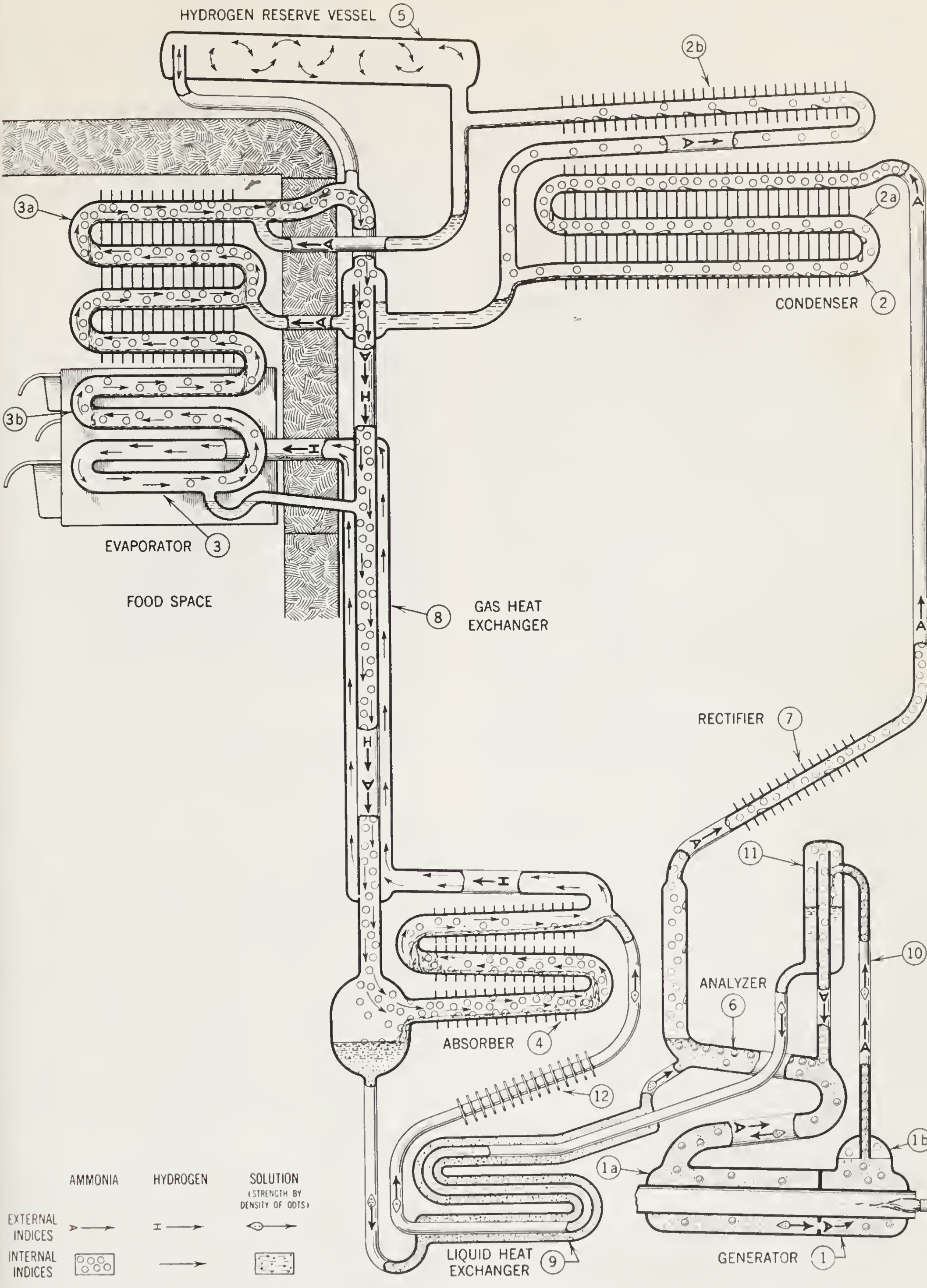
From the description it is seen that the cycle is intermittent and that the complete cycle embraces both a generating period and an absorbing period. This cycle may be easily traced from Fig. 13-2.

This in principle is the Faraday refrigerator and its cycle is explained in detail in Chapter 14.

13-6. TYPICAL LIQUID ABSORBENT SYSTEM

The liquid absorbent system seems to possess some very desirable characteristics. Water at ordinary pressures and temperatures will absorb great quantities of ammonia. Ammonia absorbed in water may be easily driven from the water by the addition of heat. Also liquid ammonia has a high latent heat of vaporization.

The Servel is a domestic refrigerator which is designed to operate in a continuous cycle and has no moving parts or valves other than to control the burner flame. The refrigerant is ammonia with water used as the absorbent; hydrogen gas is utilized to create a partial pressure (Dalton's Law, Paragraph 1-18) to allow the



13-4. Diagram of the Servel absorption cycle 1, 1a, 1b generator, 2, 2a, 2b, condenser, 3, 3a, 3b, cooling coil, 4 absorber, 5 hydrogen reserve vessel, 6 analyzer, 7 rectifier, 8 gas heat exchanger, 9 liquid heat exchanger, 10 percolator tube, separator, 12 precooler.
(Copyright 1955 by Servel Inc.)

ammonia to evaporate at a low pressure.

In Fig. 13-4, A represents ammonia, and H is hydrogen.

When the burner is lighted and its heat applied through the center of the generator, ammonia vapor is released from the solution. This hot vapor in part (1b) passes upward through the percolator tube (10), and as the hot ammonia vapor rises through this tube it carries the solution to the upper level of the separator (II).

Most of the liquid solution settles in the bottom of (11) and flows through the liquid heat exchanger (9) into the absorber (4). The hot ammonia vapor being light rises to the top of (11) tube. The hot ammonia vapor then passes downward through the center tube, into the analyzer (6). Here any water vapor is removed while the hot ammonia vapor rises into the rectifier (7).

The rectifier consists of a series of small baffle plates, surrounding the tube. If the hot ammonia vapor still has some traces of water vapor, it must be removed to insure pure ammonia vapor.

The heat has at this point completed its work. For the remainder of the cycle, the natural force of gravity is depended upon to create circulation.

The pure hot ammonia vapor continues into the condenser (2).

The air, passing through the fins takes out the heat from the ammonia vapor, thus condensing some of the vapor in liquid in (2a). This ammonia is now in a pure state, and it flows into the evaporator (3d).

The ammonia gas that does not condense in (2b) where the rest is condensed drains to the upper tube or trap.

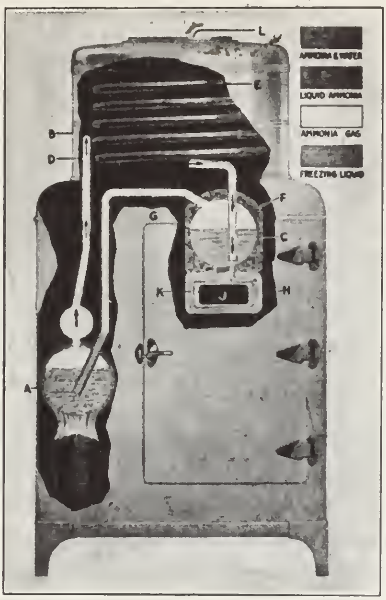
The U-tube is the receiving and storage compartment in the cycle where the liquid ammonia is allowed to build up to a predetermined level; then it flows into the cooling coil (3a). Because a liquid will always seek its own level, the liquid ammonia flows by gravity through the liquid ammonia tube and spills into the cooling unit.

As the liquid ammonia falls into the cooling unit, (3a and 3b) it forms in large shallow pools on a series of horizontal baffle plates. The hydrogen that is being fed to the cooling unit permits the liquid ammonia to evaporate, (Dalton's principle) at a low temperature. During this process of evaporation, the ammonia absorbs heat from the food compartment of the refrigerator and causes the water in the ice-cube containers to freeze. The more hydrogen and less ammonia the lower the temperature. The evaporator vapor formed by the evaporating of the liquid ammonia, mixes with the hydrogen. This mixture is heavier than hydrogen alone and moves downward through the middle of the gas head exchanger (8) into the absorber (4). This circulation is continuous in the cooling unit. The mixed gases that pass through the gas heat exchanger cool the hydrogen rising in the outer tube.

During this time a weak solution of ammonia and water is flowing from the generator (11) to the top of the absorber (4) by way of the liquid heat exchanger (9). Here it meets the mixture of hydrogen and ammonia vapor coming from the evaporator by way of the gas heat exchanger. The weak solution absorbs the ammonia vapor. The hydrogen is left free; since hydrogen is insoluble in water and is very light, it now rises to the top of the absorber and returns to the cooling unit by way of the gas heat exchanger (8).

The absorber (4) has fins and is air cooled. The cooling of the weak solution helps it to absorb the ammonia gas out of the mixture of ammonia and hydrogen. Also when the weak water solution absorbs the ammonia gas, considerable heat is liberated and the air cooled fins must remove this heat to permit refrigeration to continue.

The solution, now a strong solution of ammonia and water, drops to the bottom of the absorber (4) and continues down through the liquid heat exchanger (9).



13-5. The generation or heating interval in a typical intermittent type absorption refrigerator.
(Perfection Stove Co., Inc.)

The liquid heat exchanger carries the strong liquid, or refrigerant, back to the analyzer (6) and to the generator where it again starts its cycle.

The rectifier (7) insures that any water vapor still in the ammonia will condense and drain back to the analyzer.

The apparatus is a welded assembly. There are no moving parts to wear out and go out of adjustment. The total pressure throughout the cycle is about 200 psig, necessitating a rugged construction which insures a long life.

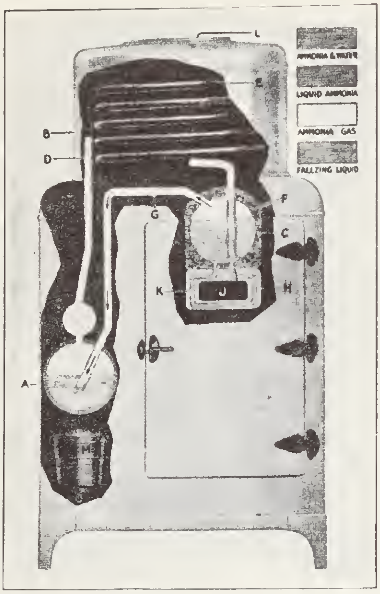
To produce a 0 F refrigerant in the cooling coil the ammonia must boil at 15.7 psig, which means that the hydrogen must make up the remainder of the pressure (184.3 psig). This refrigerator is considered to be unique among the domestic ones sold in the United States. A more detailed study is made of the Servel in Chapter 14.

13-7. KEROSENE BURNING REFRIGERATORS

A very convenient refrigerator cycle for localities not furnished with gas or electricity is the Superfex and Trukold cycle. The Superfex cycle is basically the Faraday principle but incorporates features which warrant a description.

Ammonia is mixed with water in a tank or generator (A) under which are located some kerosene burners (M). The burners are lighted and the heat produced drives the ammonia in vapor form out of the mixture. This ammonia vapor is forced up a pipe (D) and through a coil (E) which is immersed in water contained in a tank (B) on top of the refrigerator (note arrows Fig. 13-5). The lower temperature causes the ammonia vapor to change back to a liquid at the high generating pressure. This liquid ammonia drops through a pipe into the liquid receiver (C) and from here it passes to the cooling unit (K) which is surrounded by a brine (H). The liquid receiver is insulated (F) to prevent this container from overcooling the food compartment by acting as the cooling coil. This process continues for a relatively short time until all the kerosene is consumed and the burners automatically go out. As the absorber cools to room temperature, the ammonia will evaporate at a very low temperature in the cooling unit because as the generator cools it tends to re-absorb the ammonia gas, thereby reducing the pressure and permitting the liquid ammonia in the evaporator to boil at low temperatures. This evaporation causes the cooling effect on the contents of the food compartment which is called refrigeration.

In detail, the water in the generator (A) cools very quickly after the burners have gone out, and as cool water has a strong affinity for ammonia, the ammonia vaporized in the



13-6. The cooling period in an intermittent type absorption refrigerator.
(Perfection Stove Co., Inc.)

cooling unit passes back (note arrows Fig. 13-6) to the generator through a connecting pipe (G) and is re-absorbed by the water in the generator maintaining a low evaporating pressure in the cooling unit.

In other words, the heat from the oil burners drives the ammonia from the generator (A) to the cooling unit (K) in a short time; the ammonia in the cooling unit vaporizes and passes back to the generator slowly over a period of twenty-four to thirty-six hours. The vaporization of the ammonia in the cooling unit produces the refrigerating effect.

For additional efficiency in unusually hot climates or for handling extra large loads, a depression (L) in the top of the condenser tank may be filled with water which will evaporate rapidly and aid the cooling of the tank.

This refrigerator is also explained in Chapter 14 along with the Trukold and Icy-ball which are fundamentally similar to it.

Without exception the absorption mechanisms are provided with a fuse plug which will release the charge from the mechanism when the temperature of the unit becomes excessive 175-200 F. This device prevents any possibility of the complete mechanism exploding.

An absorption refrigerator using sulphur dioxide as the refrigerant was produced a few years ago but did not continue on the market. It was of the intermittent type using silica-gel as the absorbent material. The action was very similar to action in the intermittent types just explained. This absorption system is used on some railroad freight cars.

13-8. REVIEW QUESTIONS

1. Name the lettered parts of Figure 13-2.
2. Why is the ammonia and water combination so popular?
3. What purpose does the hydrogen serve in the Electrolux?
4. What localities are especially in need of the kerosene-fired intermittent absorption refrigerators?
5. Who first discovered the absorption principle?
6. Why must the absorber be cooled in the Servel cycle?
7. What is the purpose of a heat exchanger?
8. How can burning more gas in the Servel cycle produce more cold?
9. Why is the storage cylinder or receiver in the Superfex refrigerator insulated?
10. Why are these mechanisms provided with a fuse plug?
11. Name three substances used in absorption refrigerators to absorb the refrigerant gas.
12. In absorption refrigerators, does the liquefication of the refrigerant depend upon compression?
13. Does the generator serve any other purpose in the Superfex? What?
14. Have absorption refrigerators using sulphur dioxide ever been used?

Chapter 14

ABSORPTION SYSTEMS CONSTRUCTION FEATURES

The refrigeration systems of the absorption type have entirely different construction features and service operations than the compression cycle systems. In Chapter 13 the absorption cycles are explained in detail. It is the endeavor of this chapter to bring out the construction features of these refrigerators.

14-1. DOMESTIC ABSORPTION SYSTEMS

Absorption system domestic refrigerators have been marketed since the 20's. These units have several advantages. They have no moving parts and therefore are virtually noiseless. Some do not require electricity and can provide refrigeration where electricity is not available.

There are two types of absorption machines; the intermittent type and the continuous type. The intermittent type however has practically ceased to exist. The continuous type is becoming increasingly popular.

14-2. INTERMITTENT TYPE ABSORPTION SYSTEMS

The intermittent absorption machine was very popular in the 30's. The Crosley Corp. manufactured the Icy-Ball, the Superfex was made by the Perfection Stove Co. and the Trukold was sold by Montgomery Ward.

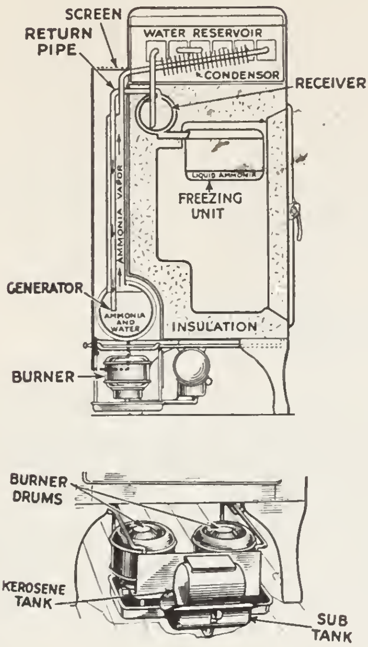
These units were operated by a kerosene heater which when lighted heated the generator for approximately one hour. After the burner used up its fuel and ceased to burn, the refrigerator would provide excellent refrigeration for about twenty-three (23) hours. Therefore, the housewife only needed to fill and light the special kerosene units once each day.

14-3. SUPERFEX

The Superfex refrigerator was designed to produce good refrigeration using kerosene as the source of energy. The system had the generator on the left side of the cabinet with the kerosene burners mounted on racks and accessible through a small door on the lower left side. The condenser was immersed in a tank of water mounted on the top of the cabinet.

The system used ammonia as the refrigerant and water as the absorbent. Note that the cooling coil was surrounded by a cold retainer which served to keep the refrigerator cold during the heating portion of the cycle.

The cycle is explained in Chapter 13. With this unit there were two precautions to be observed: The water-cooled condenser is immersed in a non-flowing water tank located in the top of the box. This water level must



14-1. The Trukold cycle and burners. (Montgomery Ward)

be kept up to the indicated level, especially just before lighting. The kerosene burners must be clean, dry, and in good condition. They must be filled to the correct indicated level and must be in a level position when burning or an improper flame will result. No obstructions should be placed over the heating flue as this will restrict the efficiency of the cycle.

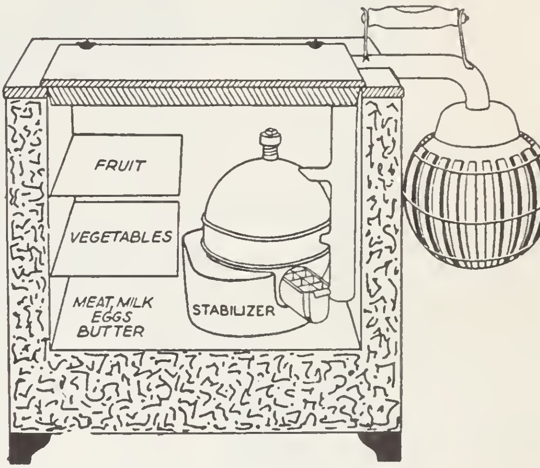
14-4. TRUKOLD

Another kerosene-fired absorption refrigerator was distributed by Montgomery Ward. This refrigerator was intermittent in operation; it used ammonia and water as the refrigerant and absorbent. A kerosene stove was located under the box and the heating flue was behind the box, Fig. 14-1.

Note the location of the liquid ammonia receiver inside the insulation of the cabinet behind and above the cooling coil. This location is to prevent the receiver from acting as the cooling coil. The burners are mounted on racks to make shifting of them very simple. The water reservoir must be kept filled to the correct depth at all times.

14-5. ICY-BALL

A refrigerator, called the Icy-Ball, was made by the Crosley Corp. It was an insulated box with a top door (chest

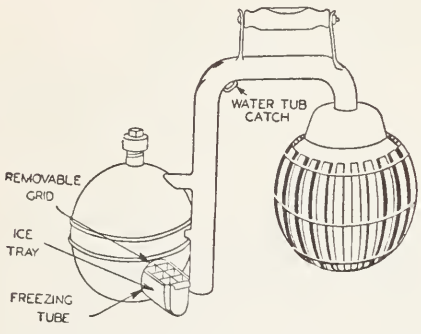


14-2. The Icy-Ball refrigerator.

model), and a portable generator and a cooling unit, Fig. 14-2. It is the absorption type and operates as follows: each refrigerator is provided with a kerosene stove and a water bucket. To start operating, place the generator over the lighted stove and the cooling unit in the bucket filled with cold water for about 90 minutes. Then place the cooling unit in the refrigerator box and the generator out in the open air. Refrigeration will be obtained for about 24 to 36 hours, Fig. 14-3. An insert in the cooling unit is provided with an ice-tray to make ice cubes. The unit weighs 39 pounds and is inexpensive to operate. It uses ammonia as the refrigerant and water as the absorbent.

14-6. CONTINUOUS TYPE ABSORPTION SYSTEMS

The continuous type absorption system has been used in the United States since about 1927. Two systems have been manufactured. The Servel system originated in Sweden and the Servel Inc. organization has the manufacturing rights. The Faraday unit was made during the early 30's. It was not a true continuous system but operated the generating and freezing portions of the cycle automatically.



14-3. The refrigerating mechanism used in the Icy-Ball Refrigerator.

The continuous absorption system is one that can simultaneously condense and evaporate the refrigerant.

14-7. THE SERVEL ABSORPTION SYSTEMS

As explained in Chapter 13, the Servel system operates on the principle of Dalton's Law of partial pressures. The Servel has been manufactured in three basic styles. The original unit used water to cool the condenser and the absorber. In Europe, an electric heating element was used, while in the United States all the units were heated with artificial or natural gas. The water-cooled units were produced between 1927 and 1933.

In 1934 and 1935, a secondary cooling system was used in place of water cooling. The ammonia condenser was air cooled and the absorber was cooled by a methyl chloride coil and the hot methyl chloride was in turn cooled by an air cooled condenser located just beneath the ammonia condenser.

Starting in 1936, the secondary system was discontinued and both the ammonia condenser and the absorber are now directly air-cooled. See Fig. 14-4.

14-8. THE SERVEL WATER COOLED SYSTEM

The first absorption refrigerator to become popular on the market was the Servel. In both Chapters 13 and 15 the operation and control of the Servel refrigerator are discussed in detail. In Chapter 13 the cycle is discussed, while in Chapter 15 the valves and their adjustments are explained.

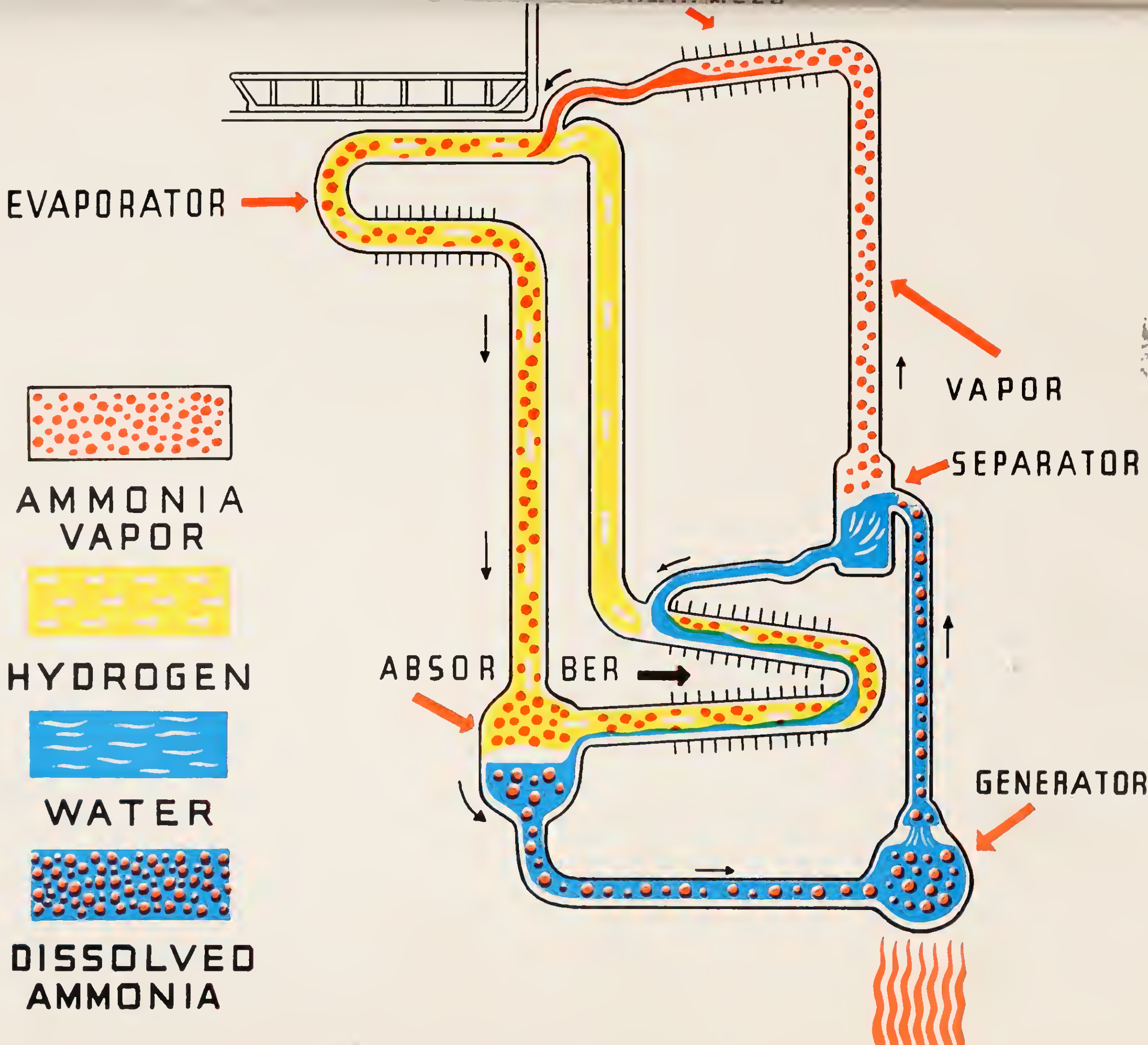
Gas is used to supply the heat energy necessary for operation, and water is used as the cooling medium. When connecting the refrigerator to the sources of supply of gas and water, valves both manual and automatic must be installed. A manually adjustable pressure reducing valve, a strainer, and a manual shut-off valve are installed in the water line. A pressure reducing valve, a manual shut-off valve, a strainer, an automatic temperature shut-off, a temperature control, and a safety cut-out are installed in the gas line to handle the gas supply to the burner.

The Servel, besides being offered in the domestic cabinet, is also obtainable in water coolers.

14-9. THE AIR COOLED ELECTROLUX SYSTEM

Servel, Inc. announced their secondary system air-cooled unit in 1933 and continued the model with cabinet refinements in 1935.

The Servel air-cooled unit is charged with a small quantity of aqua-am-



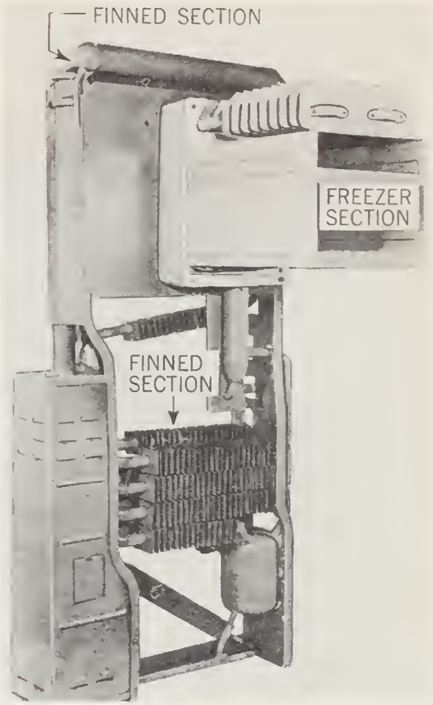
14-4. The air-cooled Servel refrigeration cycle.

monia (distilled water and ammonia) and hydrogen. The charge distributes naturally in the unit; the liquid seeks the lowest levels and the hydrogen and ammonia gas fill the remaining space.

Referring to Fig. 14-4, the application of heat at the generator, ammonia vapor is driven from the strong solution, is raised through the pump tube to the weak liquid separator. Ammonia vapor with traces of water vapor, is driven off in the separator, leaving the aqua-ammonia solution comparatively weak in ammonia (weak solution). The hot ammonia vapor then passes from the separator to the condenser. When the hot ammonia vapor reaches the condenser it is liquefied by cooling. The condenser is finned, and natural convection produces a steady flow of air over it. The liquid ammonia maintains a level in the condenser, causing the liquid ammonia to flow into the cabinet evaporator. The ammonia evaporates and absorbs heat in the evaporator.

An atmosphere of hydrogen gas, continually sweeping the surface of liquid ammonia in the evaporator, keeps removing the ammonia vapor and causes continued evaporation. The ammonia vapor thus formed in the evaporator mixes with hydrogen gas, and the mixture is made to flow through the evaporator. The long column of heavy gas, rich in ammonia (ammonia and hydrogen mixture) readily overbalances the short column of heavy gas in the evaporator, thereby causing the desired flow in the cooling coil. A flow of weak solution, being returned from the generator, contacts the ammonia and hydrogen gas mixture entering the absorber, and the ammonia is dissolved. The hydrogen being light returns to the evaporator.

The heat, which is liberated by absorption of ammonia in the absorber is carried away by air cooling. From the absorber the strong solution is returned by gravity to the generator. Continued refrigeration is merely a repetition of this cycle.



14-5. An air-cooled Servel System which uses a kerosene burner as the heat source.

The refrigeration mechanism that contains the ammonia is made of welded steel. The fins on the ammonia condensers are made of copper, although the tubing is steel. The gas controls are almost identical with those used in the water-cooled unit (Chapter 15).

Several different types have been manufactured. The refrigerators can be obtained with:

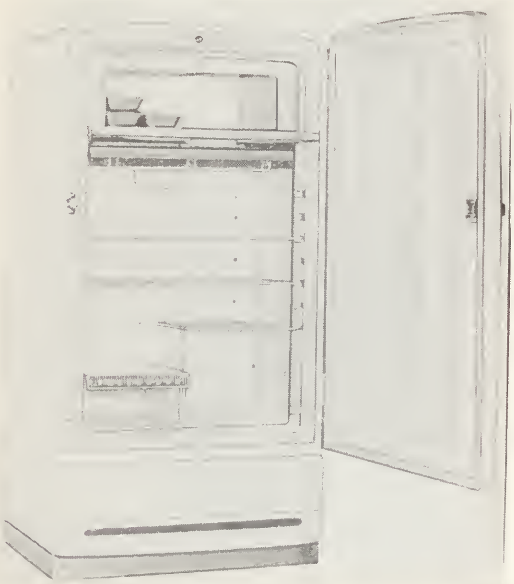
1. Gas heat
2. Electric heat
3. Kerosene heat, Fig. 14-5.

Another difference in the models is the type of generator. These generators have been made in both horizontal and vertical models.

Fig. 14-6 illustrates a late model Servel unit with an across the top

freezer. The freezer inner door is open. A phantom view of a Servel refrigerator with a horizontal generator is shown in Fig. 14-7.

The units are now equipped with automatic defrosters and some of the units use an automatic ice cube maker.



14-6. A late model Servel cabinet. Note the across-the-top freezer. This cabinet uses a kerosene burner that is located in the base of the cabinet. (Servel, Inc.)

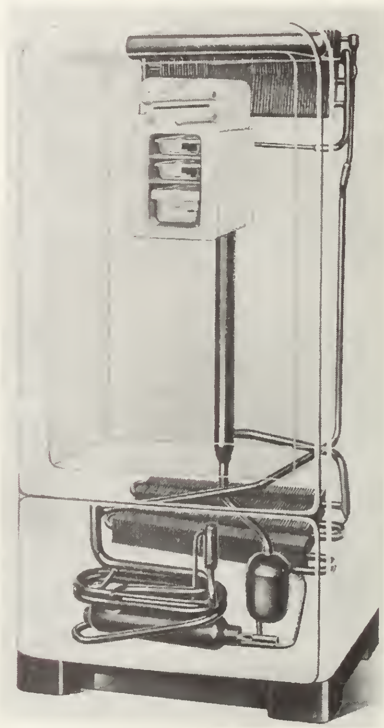
The electrical system for the more recent Servel units is shown in Fig. 14-8.

14-10. THE FARADAY SYSTEM

The Faraday Absorption Refrigerator was built by the Faraday Refrigerator Corp. It was of the solid absorbent type. The generator or absorber assembly was built as a complete unit which is located either in the bottom of the refrigerator cabinet, installed remotely, as installation conditions required.

The evaporator or cooling unit was of the plate type, and so arranged that each ice tray came directly in contact with a section of the cooling unit containing liquid refrigerant.

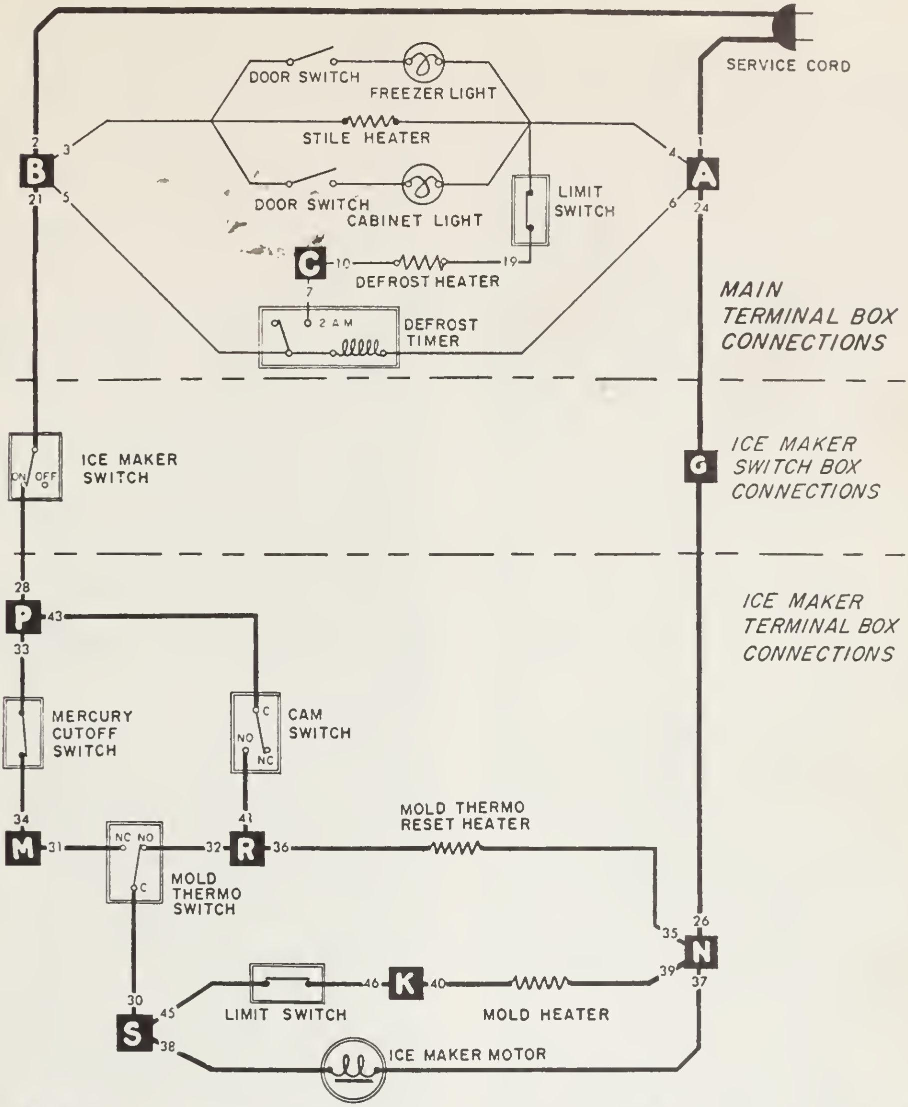
The Faraday refrigerator required a water and gas supply and employed adjustable valves to cut down and maintain constant pressure in both the supply lines. As explained before, the Faraday cycle was intermittent; therefore the main gas burner operated only a portion of the time. This necessitated a constant pilot burner and suitable control devices to open and close the gas supply to the main burner at the proper time.



14-7. A Servel refrigerator showing the installation of a horizontal generator unit. (Servel, Inc.)

14-11. THE GENERATING PERIOD

As in the original Faraday experiment, the gas burner forced the am-



14-8. The electrical circuits on the Servel. This model has both automatic defrost and automatic ice cube maker.

monia over to the other portion of the system, but the method of transferring the refrigerant was more involved than in the original setup.

First of all, in order to give a uniform heat application to the ammonia in the absorber generator, a steam bath of a low boiling temperature liquid, called F-11, was used.

From the illustration it may be seen that as this vapor became heated, its pressure rose; as the valve in this vapor circuit was closed, the vapor was locked in the chamber constructed around the ammonia absorbent.

As this vapor heated the heat was transferred to the absorbent powder, released the ammonia in gaseous form, which passed up into the water-cooled condenser. From here the ammonia passed on through the liquid line to the cooling unit, where it was stored.

However, because ammonia gas condenses at the coolest point of its circuit, a provision had to be made so the condensation would take place in

the condensing unit rather than in the cooling unit, which was naturally very cold, being inside the refrigerator box. All that was necessary was a pressure-controlled needle valve in the ammonia line which would prevent the ammonia from seeping into the cooling unit until its pressure has reached that point where it was condensable at the temperature of the cooling water. When this pressure was reached the valve would open and allow the condensed ammonia to collect in the cooling unit.

14-12. ABSORBING PERIOD

After all of the ammonia had been driven into the cooling unit, some method had to be employed to shut off the gas burner. The method used was very simple.

When all of the ammonia had been driven from the absorber there was nothing to remove the heat applied to the absorber and naturally the vapor surrounding the absorber became hot and developed a higher pressure. This pressure operated upon the F-11 vapor valve and when it had become high enough forced it open, shutting off the gas supply and allowing the F-11 vapor to recirculate.

The opening of this valve naturally caused a great drop in the F-11 pressure and due to its original spring pressure it tends to close. This, however, was prevented by a trip arrangement and lock.

It will be noticed from the main diagram that the absorber heating medium, the F-11, was so circulated that it came in contact with the condensing water. When the vapor valve was opened and this heat transfer gas allowed to recirculate, the absorber became surrounded immediately with a cold fluid. This caused a very rapid drop in the temperature of the ammonia absorbent in the absorber, which naturally put this absorbent in a position to reabsorb the ammonia driven away from it. This it did as rapidly as it could. If it were allowed to reabsorb the ammonia uncontrolled, a very low temperature would be achieved in the refrigerator box.

However, this was prevented by the temperature control unit and storing unit as illustrated. This unit operated as follows: It had a valve bellows and a spring tension manually adjusted which allowed the evaporated ammonia gas in the cooling unit to go back to the absorber and be reabsorbed only after the gases reached a certain pressure corresponding to the freezing temperature desired in the cooling unit.

When this pressure had been reached, it overcame the spring tension on the bellows; the valve opened and then closed again after the pressure had dropped.

Because this valve was manually adjustable, a temperature ranging from about 0 F. to 20 F. was obtainable in the cooling unit. This continued until the generator had reabsorbed as much ammonia as possible after which the pressure in the absorber approached the pressure of the cooling unit.

When this condition was reached it was desired that the gas valve be reopened. This was accomplished by installing a pressure bellows valve in the ammonia line, which was attached to the trip arrangement on a combination gas and F-11 vapor pressure valve.

This was designed so that, as pressure rose in the line located between the temperature control valve and the absorber, the bellows contracted and tripped the gas valve arm, which was already under spring pressure. It reopened simultaneously with the closing of the vapor valve which was attached to the same arm.

From the above explanation it will be seen that there were three liquids used in the system--ammonia as the refrigerant. F-11 (trichloromonofluor-

omethane) which was the heat transfer fluid or bath surrounding the absorber, and water which was used to condense both of the above liquids.

The system used about three pounds of ammonia and two pounds of F-11. These were, of course, sealed in the system.

The temperature control valve and the gas trip valve were also designed as service valves. The one (temperature control valve) was used to seal the cooling unit and the pressure trip valve sealed the absorber generator unit.

Whenever a remote installation was made, the chief precaution to take was in connection with the installation of the tubing connecting the above two valves. This tubing had to be dehydrated, that is, freed from water. It also had to be very clean. After hooking up this tubing to the two valves, it had to be sealed tightly to the temperature control valve and only loosely to the gas trip valve. The temperature control valve was then opened a little and the added tubing purged; that is, cleared of air by the ammonia leaking out. Then the connection of the gas trip valve was sealed.

If by chance the gas pilot light were extinguished, by becoming clogged or smothered, a thermostatic control attached to a gas valve in the circuit and the cooling of this thermostatic valve tripped to shut off the gas supply.

The water supply was practically continuous, because part of the time it was used to cool the ammonia vapor and the remainder of the time to cool the heat transfer fluid. However, the amount of water flowing was so controlled by actual requirement that the minimum amount was used most of the time.

The water valve was mounted on the side of the absorber assembly at the rear so that connections could be conveniently made. The inlet water entered the opening (A) and passed from the valve chamber to the condenser past the water valve. The water then flowed through the condenser chamber, returning to the opposite end of the water valve.

Surrounding this bellows was a liquid which expanded and contracted with the temperature of the outlet water. This expansion and contraction of liquid caused the metal bellows to move, operating the water valve. Any changes of temperature of the discharged water would change the adjustment of the valve; that is, if the discharged water became too hot, the water supply valve would be opened farther or if it became too cold, the valve would be closed more.

The gas supply was controlled by a leather valve and the gas, before it passed through this valve into the burner, was passed through a filter.

A further safety feature was introduced in a safety device operating on the thermostatic strip controlling the gas operating valve. This device was so arranged that if the absorber assembly reached too high a temperature, either from the failure of water supply or any other unusual condition, the device would trip the gas valve and shut off the gas supply.

14-13. REVIEW QUESTIONS

1. What three substances are used inside a Servel mechanism?
2. What was the purpose of the F-11 in the Faraday?
3. Why was a pilot flame used in the Faraday?
4. Why was copper tubing used in the Faraday?
5. How was the Faraday water valve manipulated?
6. What did the water cool during the freezing portion of the Faraday cycle?
7. What two purposes did the temperature control valve serve in

the Faraday?

8. What is methyl chloride used for in the secondary-cooled Servel?
9. What precautions must be taken with the kerosene in the intermittent units?
10. How is the cabinet temperature adjusted in the Servel refrigerator?
11. Why are two cooling coils used on the air-cooled Servel refrigerator?
12. Why was the liquid receiver in the Trukold placed above the cooling coil?
13. What was the refrigerant used in the Crosley Icy-Ball refrigerator?
14. What was the purpose of the tank on the top of the Superfex refrigerator?

Chapter 15

SERVICING ABSORPTION SYSTEMS

The absorption systems differ only in the mechanism for producing refrigeration. The cabinet construction is almost identical to the mechanical refrigerator cabinet and the installation and care of these cabinets is explained in Chapter 9.

15-1. GENERAL INSTRUCTIONS

The absorption refrigerator is a device to move heat from the interior of the cabinet to the outside of the cabinet. This outside heat is transmitted to the air and this air must be removed from the vicinity of the cabinet to allow cooler air to receive heat from the condensers.

Also the kerosene or the piped gas when burned form carbon dioxide gas (harmless) and steam vapor (harmless). However, to provide good air flow past the burner, these products of combustion must be moved away from the cabinet. Because warm gases rise, the absorption cabinets must have proper air flow space beneath, in back, and over the top of the cabinet.

Inside the mechanism the liquids flow by gravity and the mechanism must be properly leveled or the movement of the liquids and gases inside the unit will be uncertain.

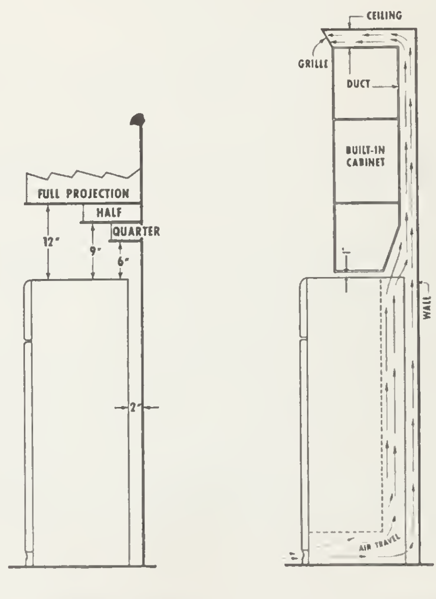
The condensers and flues of the unit must be kept clean to allow proper air flow and flue gas flow. It is recommended that the condensers and flues be cleaned at least twice each year.

15-2. LOCATION OF REFRIGERATOR

One should be careful in regards to locating the absorption refrigerator, Fig. 15-1.

1. It must be away from the sun or any other source of heat, for economical refrigeration.

2. It must be conveniently located indoors for efficient use.



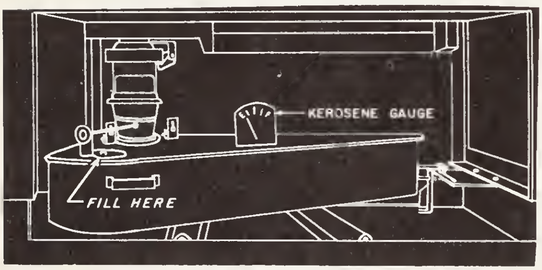
15-1. The proper location of an absorption refrigerator to allow good air circulation. (Servel, Inc.)

3. It must be placed in a room that has sufficient air movement to provide enough air for combustion and cooling.

4. It should be as near as possible to a gas supply if piped gas is to be used.

5. It must be mounted on a firm floor to maintain its position.

6. It must be mounted with the unit level to allow the mechanism liquids and gases to flow properly. A spirit level must be used to check for unit level. It is more important to level the cooling coil and the burner than it is to level the cabinet.



15-2. An absorption system kerosene burner. (Servel, Inc.)

15-3. AIR CIRCULATION

The air circulation is very important. Air must be able to freely enter the burner space and the condenser space. This same air must be able to return to the same room. If the air is ducted to another room or outside, air pressure changes may seriously hamper the operation of the flame.

Good air circulation can be easily obtained by allowing at least a 2 in. clearance in back of the refrigerator (small spaces may be used). At least 12 in. clearance must be provided above the cabinet to allow adequate escape of the condenser air and combustion products.

15-4. INTERMITTENT SYSTEMS

The intermittent systems that use a kerosene burner require very little servicing. They are manual in operation and eliminate controls by having the owner refill and light the kerosene burner. The previous instructions about air circulation and location of the cabinet also pertain to the kerosene heated units.

15-5. PROPERTIES OF KEROSENE

The kerosene needed with kerosene fired absorption units should be of the highest quality. It must burn as cleanly as possible to eliminate fuel odors and soot deposits in the flue. Kerosene is a hydro-carbon and when properly burned the products of combustion are carbon dioxide and steam. However those kerosenes with the higher flash point (up near 140F) are more likely to contain heavy carbons that may form free carbon or soot (amorphous carbon) on the flue or this soot may escape into the air. The kerosene has a heat value of about 19,000 Btu. per pound.

15-6. KEROSENE BURNERS

The kerosene burners used in the intermittent absorption refrigerators are of standard construction. A circular (cylindrical) asbestos wick carries the liquid kerosene by wetting action up to the upper edge of the wick. The height of the wick is adjustable. This wick should be in good condition, that is, it must be charred and then trimmed to match the guides. The wick must be perfectly level to its adjustable ring and the complete unit must be level, Figure 15-2.

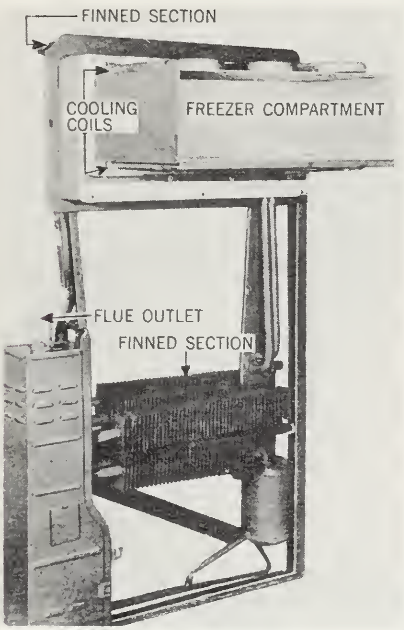
The correct flame, a blue flame with faint yellow tips is obtained by first raising the wick, igniting it, and then lowering the wick until the correct flame is obtained.

The burner must be accurately fitted to the generator flue. The distance must be closely adjusted. If the flame is too

far away, the flame will not be efficient because of excess air. If the burner is too close there will be insufficient air for good combustion.

15-7. FLUES

The heat from the burners must be efficiently transmitted into the generator. The kerosene flame and the hot gases from it are conducted along a flue that extends around the generator



15-3. The refrigerating system for a kerosene burning domestic refrigerator.
(Servel, Inc.)

or through it. These flues sometimes have spiral metal fins inside them to make the hot gases more efficiently give up their heat to the flue walls.

Because these flues carry the combustion gases they must be kept open or the combustion will not be complete. The flues must also be kept clean or much of the heat will be lost by poor heat transmission into the generator. The flue should be cleaned at least twice each year. Special flue brushes should be used for this purpose.

15-8. CABINET CARE

The cabinets are serviced exactly like those described in Chapter 9. The cabinet leveling devices are the same, the door gaskets, and the door hardware is much the same, the shelf arrangement and design are the same.

Porcelain interiors and enamel exteriors are just like the other cabinets. The door gaskets can be checked for leaks with a light bulb.

15-9. CONTINUOUS SYSTEMS

At the present time there is only one continuous absorption system in the domestic refrigeration field. The Servel (or Electrolux as it used to be called). These units receive their energy from piped gas (either artificial or natural), bottled gas, electricity or kerosene, Fig. 15-3.

The piped gas systems are equipped with gas pressure regulators, thermostats for controlling flame size, burners and burner safety shut-offs.

There are now 56 different model R-4000 series available for replacement purposes for units dating as far back as 1933. No units were made during World War II 1943-44, and 45.

These units contain less than two pounds of ammonia and use the Platen Munters system as devised and patented by the two Swedish scientists. A five cubic foot refrigerator unit contains about 1.1 pounds of ammonia, 2.6 pounds of water and 0.03 pounds of hydrogen.

The refrigerators carry two identification plates. One plate is located in the control compartment and this one is the cabinet identification plate. The other plate is located in either the frozen food compartment or the control compartment. The latter has the

heading "Absorption Refrigerating Unit."

The units are factory tested to 800 psig. which is about four times their operating pressure.

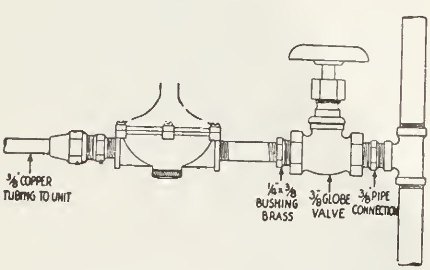
Each unit serial plate has the Btu rating of that system recorded on it.

The burner and the necessary controls are about the only parts that may need adjustment or replacement. If, however, a unit fails to operate and the trouble is not found to be in the burner or controls then the entire unit should be replaced. This is easily accomplished by removing the back from the cabinet, disconnecting the gas supply and electrical circuits and removing the entire assembly and replacing it with a new one.

15-10. GAS SUPPLY

The fuel most commonly used for the absorption system refrigerators is city or illuminating gas, although electrical heating elements are sometimes used. It must be clean fuel in order to prevent a pollution of the burner or deposit on the burners. The cleaner the fuel the less frequently the burners have to be cleaned.

The piped gas refrigerators should be supplied with gas under a steady



15-4. The gas line installation of an early model Servel refrigerator.
(Servel, Inc.)

pressure and should have a special burner for each type of gas. The gas must be strained before being admitted to the burners and must also have a pressure regulator to insure an unvarying pressure on the burner, Fig. 15-4.

It is good practice to become acquainted with the local rules on installation of these refrigerators before attempting to install them.

In all cases of burner difficulty, a check should be made to determine that the burner being used is the correct one for the gas used.

The four different gases in use as a fuel for the Servel units are:

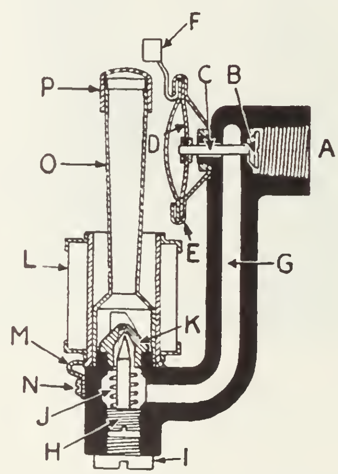
Artificial gas (425 to 600 Btu per cu. ft.)

Natural gas (600 to 1600 Btu per cu. ft.)

Liquid petroleum (L P) gas (1600 Btu per cu. ft.)

Propane gas (1600 Btu per cu. ft.)

Butane gas (1600 Btu per cu. ft.)



15-5. The "Klixon" valve and the burner used on the older model Servel units. A. Gas in; B. Poppet valve; C. Poppet valve stem; D. "Klixon" snap button; E. Retaining housing; F. Klixon disk heater; G. Gas passage to the burner; H. Manual adjusting screw for maximum gas flame; I. Seat cap; J. Spring; K. Gas nozzle; L. Screen; M. Screen retainer; N. Screen retainer screw; O. Burner venturi; P. Burner cap.
(Servel, Inc.)

15-11. CONTINUOUS SYSTEM CONTROLS

The method of heating may be by

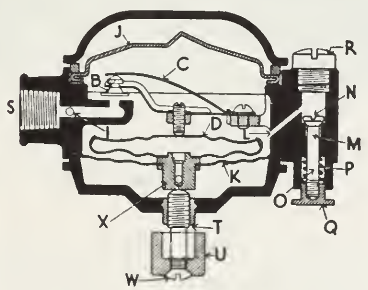
gas, liquid fuels, or electricity. At present gas is the most popular, and the method of controlling the supply is explained later.

Aside from cabinet care and cleaning, the only service (outside the factory) that may be needed on the refrigerator are heating controls. The adjustments determine the efficiency of the unit to such a great extent that these must be done carefully.

Heating gas valves are used in the absorption system to enable the automatic control of the amount of the heating gas.

The systems use a continuous gas flow.

The refrigerators must have a heating gas control of some kind. The Servel being of continuous operation, has a



15-6. The secondary system air-cooled Servel thermostatic gas control. B. Maximum flow valve; C. Maximum flow valve spring assembly; D. Thermostatic diaphragm; I. By-pass outlet; J. Body gasket sealing diaphragm; L. Burner lighter passage; M. Opening to burner lighter; N. Burner lighter valve; O. Burner lighter valve stem; P. Burner lighter valve stem; Q. Burner lighter push button; R. Burner lighter cap; S. Gas outlet; T. Thermostat adjusting screw; U. Thermostat adjusting screw knob; W. Set screw; X. Diaphragm and bulb assembly.
(Servel, Inc.)

gas volume control and a safety control. A disk valve "Klixon," temperature-controlled by the flame itself, will automatically close the gas supply if the flame goes out, Figure 15-5. A bulb pressure-temperature control located at the cooling unit controls the amount of gas burned according to the needs of the refrigerator, Figure 15-6.

It is seen from the above explanation that a great deal of the successful operation of domestic refrigerators is dependent on the functioning of the automatic control valves; it is obvious that the more the service man knows of these valves and their troubles and remedies, the less difficult the servicing operations will be.

It is also important to know about these controls for the reason they must always be in excellent condition in order to give satisfactory, dependable service. It cannot be emphasized too much that these valves are the control board for the refrigerator.

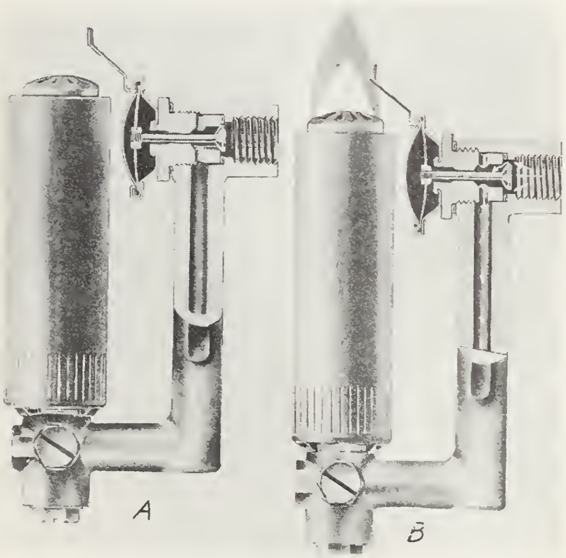
The Servel generally has its heat energy supplied by a gas burner. Several different methods have been devised for the regulation and control of this gas. In the Servel refrigerator, between the gas main and the operation controls of the refrigerator, are placed a manual shut-off valve, a strainer, and a pressure-regulating valve. As explained previously, the Servel operates on the continuous cycle and therefore gas is continually being consumed. However, to take care of variations of demand on the refrigerator itself, the amount of gas fired must be automatically controlled. This is done by the use of a pressure control valve operated by a power element located at the cooling unit. As the cooling unit warms up, the gases in the power element expand, and pressing upon a diaphragm in the control valve, open the gas control, which allows more gas to escape to the burner.

The larger flame speeds up the cycle in the mechanism and continues to speed it up until the cooling unit has again become cold enough.

As the cooling unit cools, the power element located there will cool, reducing the pressure on the gas valve diaphragm. This reduction closes the heating gas opening, somewhat reducing the size of the flame. This valve operates

similar to a temperature controlled expansion valve. Turning the adjustment clockwise or in, reduces the gas supply.

The Servel people have designed a unique valve for preventing useless waste of gas in case the flame should be extinguished. This valve is of the dished-button type and is thermostatically controlled, Figure 15-7. Being located adjacent to the flame it remains hot as long as the gas is ignited, but if the flame is extinguished, this disk will become cold; it is so designed that if it does it will snap and become dished in the other direction. This movement closes a valve in the gas line, completely shutting off the supply of the gas. If this happens, the only method possible of re-igniting the gas is to heat up this "Klixon" disk in order that it will open the safety valve again. This may be done with a match and a special burner push button mounted on the thermostat body provided for this purpose.

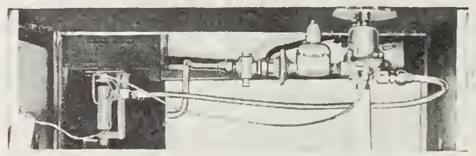


15-7. A safety shut off valve. This valve will close the gas line if the gas flame should accidentally be extinguished. A. Shows the valve in closed position; B. Shows the valve in open position.
(Servel, Inc.)

Each refrigerator has an automatic pressure control for maintaining a constant gas pressure. This valve reduces the fluctuation in pressures which always exist in the gas mains all over the country to a minimum. The supply of gas must be very constant when being fed to the Servel.

15-12. CONNECTING UNIT

The gas lines must be installed according to the local building laws, plumbing codes and recommendations. One should use the best materials available; all new materials; and the best craftsmanship.



15-8. A gas line installation for a Servel gas refrigerator. This installation varies as to the type generator used.

The gas line should be either 3/8 in. O. D. copper tubing (soft) or 3/8 in. O. D. annealed aluminum tubing. The tubing should be attached to the main gas line as close to the refrigerator as possible. The tubing must be protected from abuse. It should be protected from kinking or bending and it should be protected from heavy objects to prevent crushing. A hand shut off should be installed between the main gas line and the tubing.

At the refrigerator end the tubing has a hand shut off cock. The tubing is fastened by means of the 45 $^{\circ}$ SAE flare to the end fittings, Figure 15-8.

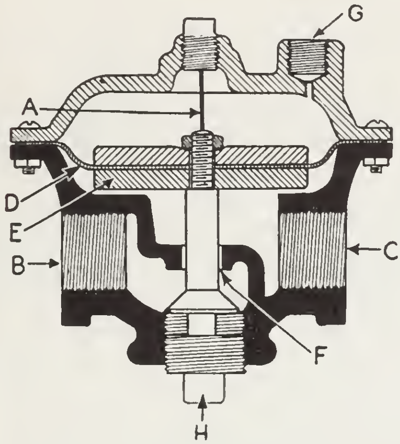
A strainer is mounted at the outlet of the shut-off cock. This strainer is of very fine mesh and it removes any dust or dirt that might injure the pressure regulator and thermostatic control.

The gas now passes through a pressure regulator to the thermostatic control, then to the burner.

After the installation is complete all the joints must be tested for leaks with a soap and water solution while under pressure and before lighting the burner.

15-13. PRESSURE REGULATING VALVES

The purpose of the pressure regulating valve is to supply a steady flow of gas to the burner. If the burner gas



15-9. A pressure regulating valve for gas. A. Shipping pin; B. Gas in; C. Gas connection to the thermostatic control; D. Flexible diaphragm; E. Weights; F. Valve and seat; G. Bleeder Connection; H. Valve cap. (Servel, Inc.)

pressure should change, the flame would change and may even be extinguished.

The pressure regulator both reduces the pressure and provides a constant gas pressure, Fig. 15-9.

Liquid petroleum (LP) gases do not need a pressure regulator at the refrigerator because the pressure regulator mounted on the LP cylinder performs the same duty.

The pressure regulator operates much as an expansion valve does. The outlet pressure presses against a diaphragm (synthetic rubber, fabric reinforced) and if the pressure attempts to lower the diaphragm will move, opening the gas valve allowing more gas to flow. The increased gas flow will press the diaphragm up tending to close the valve. The pressure regulator is very delicate. It is accurate to 1/100 of an inch water pressure. The pressures the regulator has to maintain vary from 3.9 inches of water to 1.6. This pressure needed varies with gas flow in cu-ft per hour. This gas flow is controlled by the orifice size in the burner. The pressure also varies with the density or specific gravity of the gas. The greater the gas flow the greater the pressure needed. The pressures must be adjusted to within .1 inch water pressure for good results.

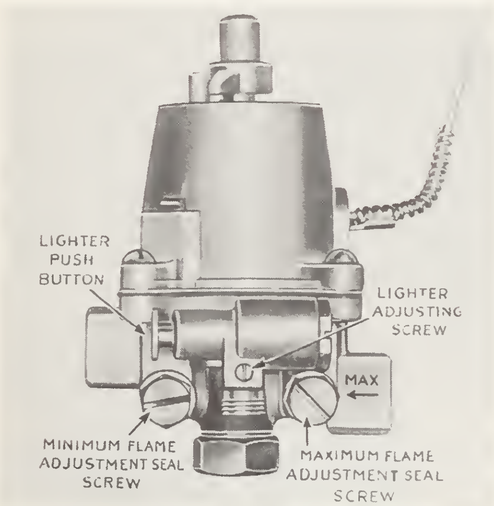
15-10. A diagram of the operation of the thermostat on the Servel refrigerator. (Servel, Inc.)

The Servel company should be consulted in reference to the best gas pressures for each particular refrigerator. They use different capacity

orifices to enable them to bring the units to maximum efficiency.

15-14. THERMOSTAT

The mechanism varies the amount of cooling by varying the amount of heat. The more heat fed to the generator the cooler the evaporator will become. A thermostat is used to perform



15-11. The Servel thermostat showing adjustments and lighter push button. (Servel, Inc.)

this job. A thermal bulb clamped to the cooling coil will create pressure if the cooling coil becomes warmer. This pressure is carried to a diaphragm by a capillary tube. An increase of pressure in the diaphragm opens the gas valve and more gas flows to the burner, Fig. 15-10.

The increased cooling resulting from the added heat will cool the thermal bulb and the diaphragm pressure will decrease, closing the valve. This control was put on 1947 models and later. Note the capillary tube, the temperature adjusting knob on the top of the body, and the minimum and maximum devices located on the body, Fig. 15-11.

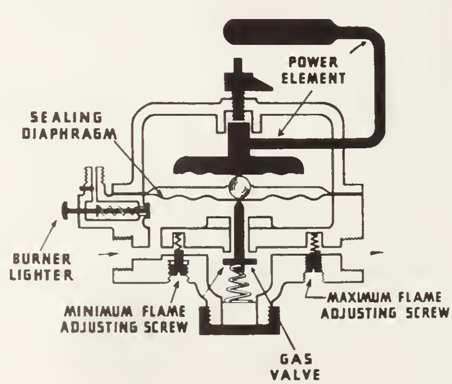
The inner working of the thermostat is shown in Figure 15-12. This illustration shows the construction of the minimum and maximum flame adjustments, and also the details of the burner lighter mechanism.

The amount of primary air is adjustable. The outer casing of the burner, called the air shutter barrel, can be turned. It should be very carefully adjusted to give an all-blue flame just as the yellow disappears from the flame. Too much primary air will also give a blue flame but the flame cone will be sharp and the flames will hiss more sharply.

15-15. BURNER

The burner is the mechanism used to carefully mix the air with gas in the proper proportion and burn the mixture to provide the most efficient heat. It is basically a Bunsen type burner, Figure 15-13.

The gas enters at the top, travels past the safety valve and passes through the turbulator, through the carefully sized orifice sperd, mixes with the primary air, burns at the end of the mixing tube where the secondary air and the heat enters the generator tube



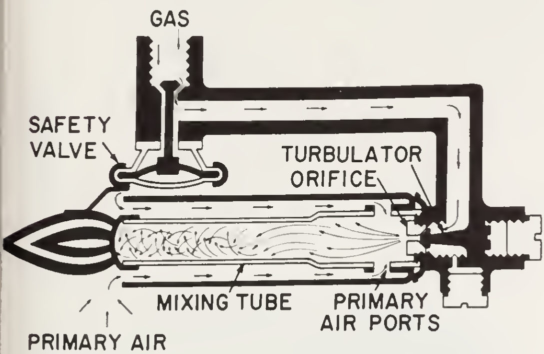
15-12. A sectional diagrammatic view of the Servel thermostat. The gas flows from left to right. Note the burner lighter button and mechanism. (Servel, Inc.)

and flue. The fitting at the lower right (at the bottom) is the opening that is connected to a manometer to check the gas pressure.

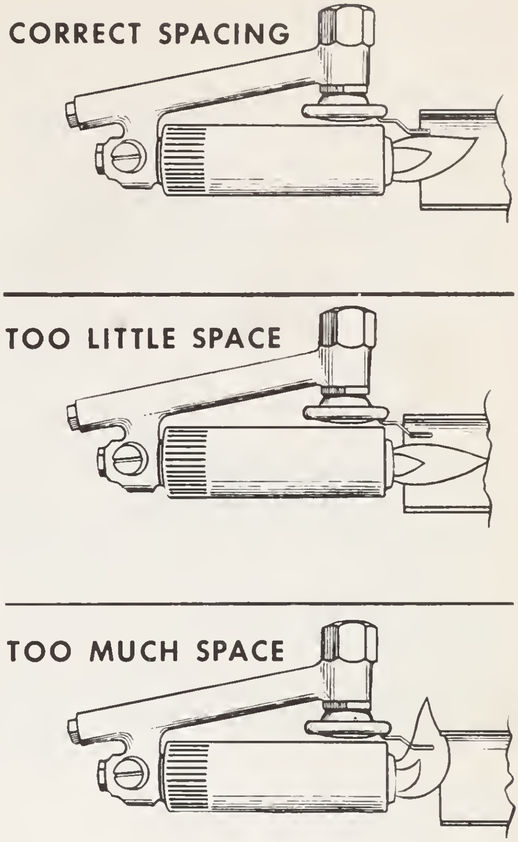
Four different types of burners are available, each for a different kind of gas. Type A is for fast burning gases and Type D is for liquified petroleum (LP) (bottled) gas.

The turbulator is available in different models; one groove type is for L P gases, the two groove type is for piped gases.

The burner must be exactly the right distance from the generator flue



15-13. A sectional view of the horizontal type burner, the safety valve and the flame. (Servel, Inc.)



15-14. The effect of burner spacing on the minimum flame. (Servel, Inc.)

to obtain the correct amount of secondary air, Figure 15-14.

The burner can be adjusted to the distance it is mounted from the generator flue and it can also be moved to center the flame in the center of the generator flue. The flame must never touch the flue. Use a mirror if it is difficult to see the flame location.

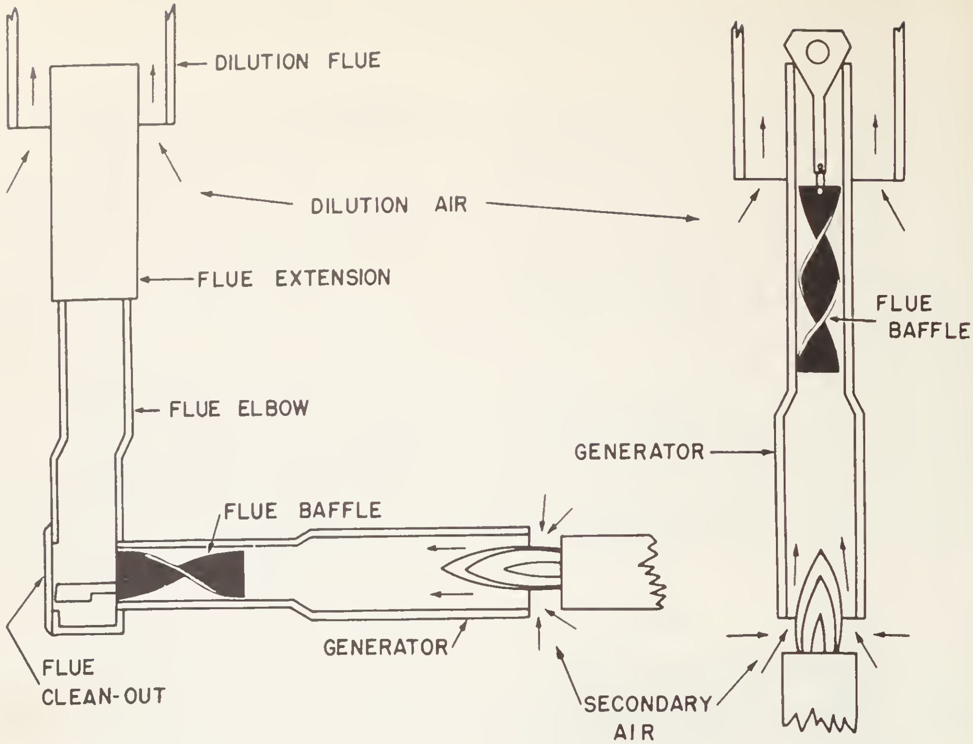
The products of combustion are harmless and there is no odor.

15-16. BURNER SAFETY VALVE

It is very unlikely the burner flame will ever be snuffed out. But if someone should shut off the gas accidentally and then turn it on or if someone accidentally puts out the flame by spilling mopping water the burner has a positive safety device that prevents unburned gas from escaping.

This safety valve is operated by the flame. A metal plate touches this flame and becomes quite hot. This heat is transmitted to a bi-metal disc, which will move with a snap action and open the gas valve when hot. If this disc cools somewhat the bi-metal disc will dish the other way pulling the valve shut and stopping all gas flow.

It is important that the heat conductor strip be kept up against the outer edge of the flame.



15-15. The flue construction for both the horizontal and the vertical generator type Servel units. (Servel, Inc.)

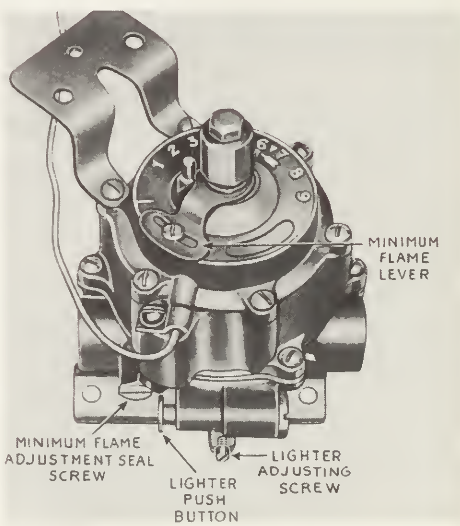
15-17. FLUE

The flue is a circular passage through the generator and then up the back of the unit. Its purpose is to provide passage for the flame gases. It must work efficiently to provide enough air movement to allow the flame to operate correctly, Figure 15-15.

The first section of the flue is within the generator itself. This is the heat transfer surface and the hot gases must transfer as much heat as possible to the generator. A twisted metal flue baffle is inserted in this part of the flue to twist the hot gases to make this heat transfer efficient.

This baffle is removable and movable. It can be used to clean out the flue periodically by moving in and out of the generator flue (it is best to turn the thermostat to minimum flame during this operation).

The second section of the flue is the flue extension. An air opening is provided where the two meet. This opening permits dilution air to enter the



15-16. A semi-automatic defrosting thermostat for Servel units. (Servel, Inc.)

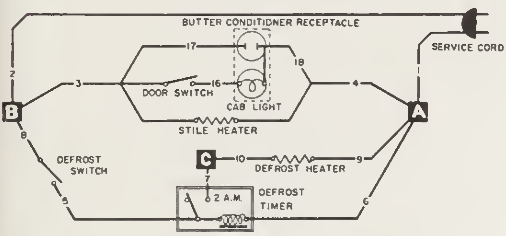
flue. This flue is basically the chimney and it must be kept clean to insure correct air movement.

15-18. AUTOMATIC DEFROSTER

Several models of the Servel continuous system have defrosting devices.

The semi-automatic defroster consists of setting the thermostat to a minimum flame (or defrost position) and when the cooling coil has defrosted, the thermostat will automatically start normal operation again, Figure 15-16.

The automatic defroster is controlled by an electric timer. At whatever time the owner prefers usually in the early morning hours (1 a.m.) the electric clock stops the operation of the thermostat and sends electrical energy through resistance wires located under the cooling coil. The heat from these wires quickly defrosts the outer portion of the cooling coil without disturbing the frozen foods within the coil. When the coil is defrosted, the system automatically returns to normal operation, Figure 15-17.



15-17. A wiring diagram of the automatic defrosting system.
(Servel, Inc.)

15-19. ICE CUBE MAKER

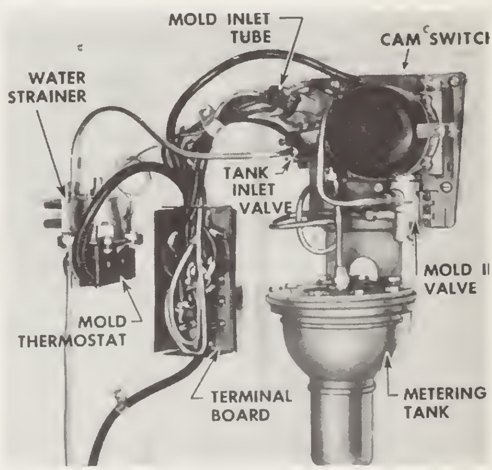
Some of the Servel units have a device which automatically manufactures ice cubes as they are needed.

A wire basket is used to hold the ice cubes. If this basket is not full, an electrical circuit is closed which opens a water valve and fills the ice cube freezer trays. When the water is at the correct level, the water flow stops, Figure 15-18. Then when the water is frozen, a thermostat closes a heating circuit to loosen the ice cubes, a small electric motor rotates the ice cube apparatus and the cubes are unloaded into the basket. If the basket is still not full, the cycle is repeated.

15-20. SERVICING THE SERVEL

It is strongly recommended that one take training from a Servel service engineer before attempting to service the Servel units.

The most important observation to be made in servicing the Servel gas-fired refrigerator is to determine that the gas furnished the refrigerator is supplied in the correct amounts and pressure.



15-18. The Servel automatic ice cube maker.
(Servel, Inc.)

The amount of gas fed to the refrigerator may be checked by the size of the flame and may be adjusted by the use of the automatic temperature-

controlled gas valve which has a manual adjustment on it. Always check the gas pressure using the water filled manometer. The flue must be kept perfectly clean to allow a good transfer of heat. Brushes are used for cleaning the flue.

The fins on the ammonia condenser, and, or the absorber must be cleaned periodically to insure good heat removal from these surfaces.

First, temperature control dial set too cold which may be the case when the customer has not been properly instructed in its use.

Secondly, the temperature of the cooling unit may be lower than that indicated by the temperature control dial setting.

A time temperature graph should be taken of such a machine which will tell much more clearly what is wrong.

15-23. LITTLE OR NO REFRIGERATION

Little or no refrigeration may be due to an overloaded cabinet but if this is not the trouble, it may be due to one of the following: little or no refrigeration is due principally to either improper condensing temperatures, or little or no heating of the generating unit. If the condenser or absorber are dirt and lint covered, poor refrigeration will result, due to the high temperature of these two parts.

If the gas supply has been shut off, or if the line has become clogged, resulting in a very small consumption of gas there is naturally little or no refrigeration. This trouble may be traced by checking the gas pressures at the burner.

Two other reasons for poor heat transfer or poor heating of the generating unit are: a restricted gas flue, or an insulated gas flue. After a certain period of use the flue of the generator may become coated with a soot deposit, preventing a rapid transfer of heat from the gas flame to the generator body. This soot deposit should be removed periodically (1-2 months) to insure proper refrigeration and to reduce gas consumption.

When scraping the flue of a generator or when removing the soot from any surface of the generator, considerable care should be taken to prevent injury to the surface. Always put papers or a cloth under the refrigerator when cleaning the flues. The gas-fired and kerosene-fired refrigerators are equipped with flues to direct the hot gases around and away from the generating units. Occasionally these flues are clogged by placing the refrigerator too close to the wall, by placing objects over the opening, or by having some obstruction fall into it. These flues must be kept clean to insure proper functioning of the refrigerator.

A Servel unit which has not been used for a period of time may refuse to freeze when started. To remedy this trouble, remove the unit from the cabinet and invert it for approximately 1/2 to 1 hour. Right the unit and install it in the cabinet.

15-24. REVIEW QUESTIONS

1. Why must the absorption unit be leveled?
2. How is proper air flow obtained?
3. Is kerosene sometimes used as the fuel for continuous systems?
4. What is a flue?
5. How is the gas pressure in a piped gas system measured?
6. Why don't L P systems need a pressure regulator in the base of the cabinet?
7. How is the temperature regulated in a piped gas continuous system?
8. Why doesn't the flame go out

when the cabinet is cold enough on the continuous piped gas systems?

9. What are the two basic causes for insufficient refrigeration in a continuous system?
10. How are some of the Servel units automatically defrosted?

Chapter 16

HERMETIC UNITS

The hermetic refrigerator condensing unit consists of a mechanism which provides a single housing in which the motor and compressor are permanently sealed. These hermetic units may be grouped according to the following five general classifications.

1. All the joints are soldered or welded and there are no service valves.
2. All the joints are mechanical (assembled with bolts or screws) and there are no service valves.
3. All the joints are soldered or welded and there are service valves.
4. All the joints are mechanical and there are service valves.
5. Combinations of the above four types.

16-1. DEVELOPMENT

The refrigeration industry has long recognized the engineering and production problems involved in the design, production and servicing of the conventional compressor crankshaft seal. A natural evolution was the elimination of the need for the compressor crankshaft seal by constructing the motor inside the compressor housing. This improvement has been dependent on the development of such things as insulating materials, refrigerants, motor designs and motor controls. The General Electric Corporation's Monitor Top was the first hermetic unit that reached the market in large quantities. It was first introduced in 1926 and proved very successful. It was a sulphur dioxide charged unit with a compressor and motor under a dome surrounded by the condenser, all mounted on top of the refrigerator cabinet. The system used a high side float refrigerant control and had a magnetic relay starter.

Several hermetics appeared on the market such as the Majestic, the Grunow and others during the period of 1926 to 1934. In 1934 the Frigidaire Corporation introduced the Meter Miser in their domestic units. The following six years found many of the manufacturers developing the hermetic system. With the exception of the war time lag in production, this trend has continued. Today, practically all of the domestic units are either full hermetics, partial or semi-hermetics. The units are being made more compact. The cabinets are refrigerated their full height, Figure 16-2. They are either equipped at one extreme with two complete refrigerating units, one for frozen foods and the other for regular refrigerating temperatures, or they may have a secondary evaporator and condenser to provide the refrigeration for the refrigerator (non-freeze) compartment, or they may have but one cooling coil for both the frozen foods compartment and for cooling the cabinet. Figure 16-1. All new models provide much more storage capacity, using the same outside cabinet dimensions, than the older designs. This increase in storage

16-1. A late model refrigerator which has considerable more usable space as a result of the mechanism being made more compact.
(Kelvinator Div., American Motor Corp.)

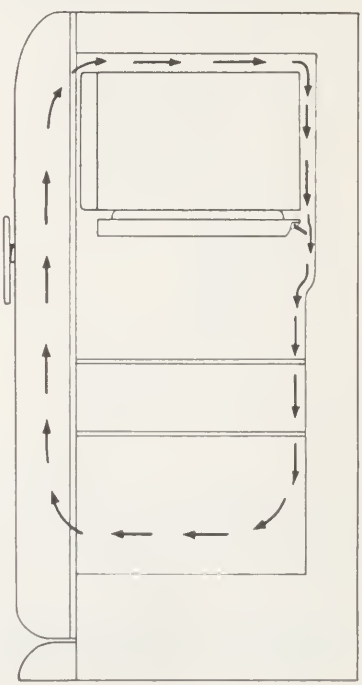
capacity is due to the more compact refrigerating units and the more effective and thinner insulation.

16-2. TYPICAL HERMETIC CYCLES

The hermetic units in use today are refinements of the units introduced in the 1940 and 1942 units with very few basic changes. Most of the condensing units are located in the bottom of the cabinet and use a split-phase motor connected to either a reciprocating or rotary compressor. The condenser is usually the natural convection type, called static condenser. The refrigerant control is a capillary tube or a combination of the weight check valve and the capillary tube. The cooling coil is commonly made of aluminum or stainless steel and provides considerable volume and shelf space for frozen food storage, ice cube making and also cools the refrigerator cabinet. The refrigerant lines are usually silver brazed in place and the unit is designed to be removed in one piece, usually from the back of the cabinet. The electrical system comprises a starting relay, several protective devices, a motor control; which in some makes has a clock-operated defrosting mechanism, a cabinet light, and a door switch.

Various methods have been developed to provide the two different temperatures required in refrigerators which incorporate frozen foods compartments. It must be remembered that the frozen foods compartment temperature must be maintained at 5 F. or below. The other refrigerated compartment temperature must not fall below 32 F. (usually maintained at 35-45 F.). Below 32 F. many foods will freeze and be destroyed. The various methods of obtaining controlled temperatures in each compartment are:

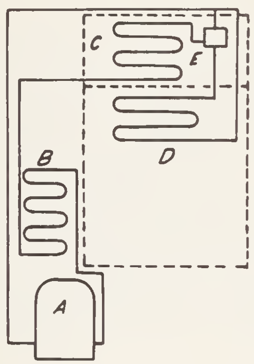
1. Air spill over using one cooling coil, Fig. 16-2.
2. Refrigerant spill over using two



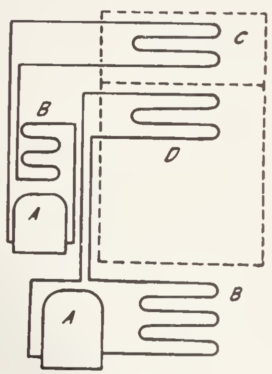
16-2. A spill over from the frozen foods compartment refrigerates the normal storage cabinet.
(Crosley Div., Avco Corp.)

cooling coils, Fig. 16-3.

3. Two complete and independent refrigerating mechanisms, Fig. 16-4.
4. A secondary refrigerant system in which a secondary refrigerant in a closed system picks up heat in the refrigerator cabinet and



16-3. Refrigerant spill over from the frozen foods coil refrigerates the normal storage cabinet. A. Compressor; B. Condenser; C. Low temperature cooling coil; D. High humidity cooling coil; E. Accumulator.



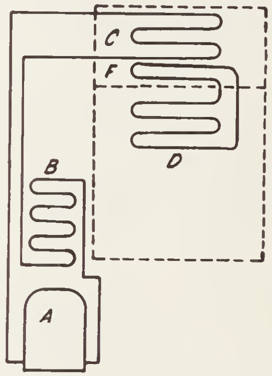
16-4. This two temperature box is refrigerated by two complete and independent refrigerating mechanisms. A. Motor-compressor; B. Condensers; C. Low temperature cooling coil; D. High humidity cooling coil.

gives it up to the freezing compartment coil, Fig. 16-5, Fig. 16-6.

5. A two temperature valve operating on the refrigerator (highest temperature) coil, Fig. 16-7.

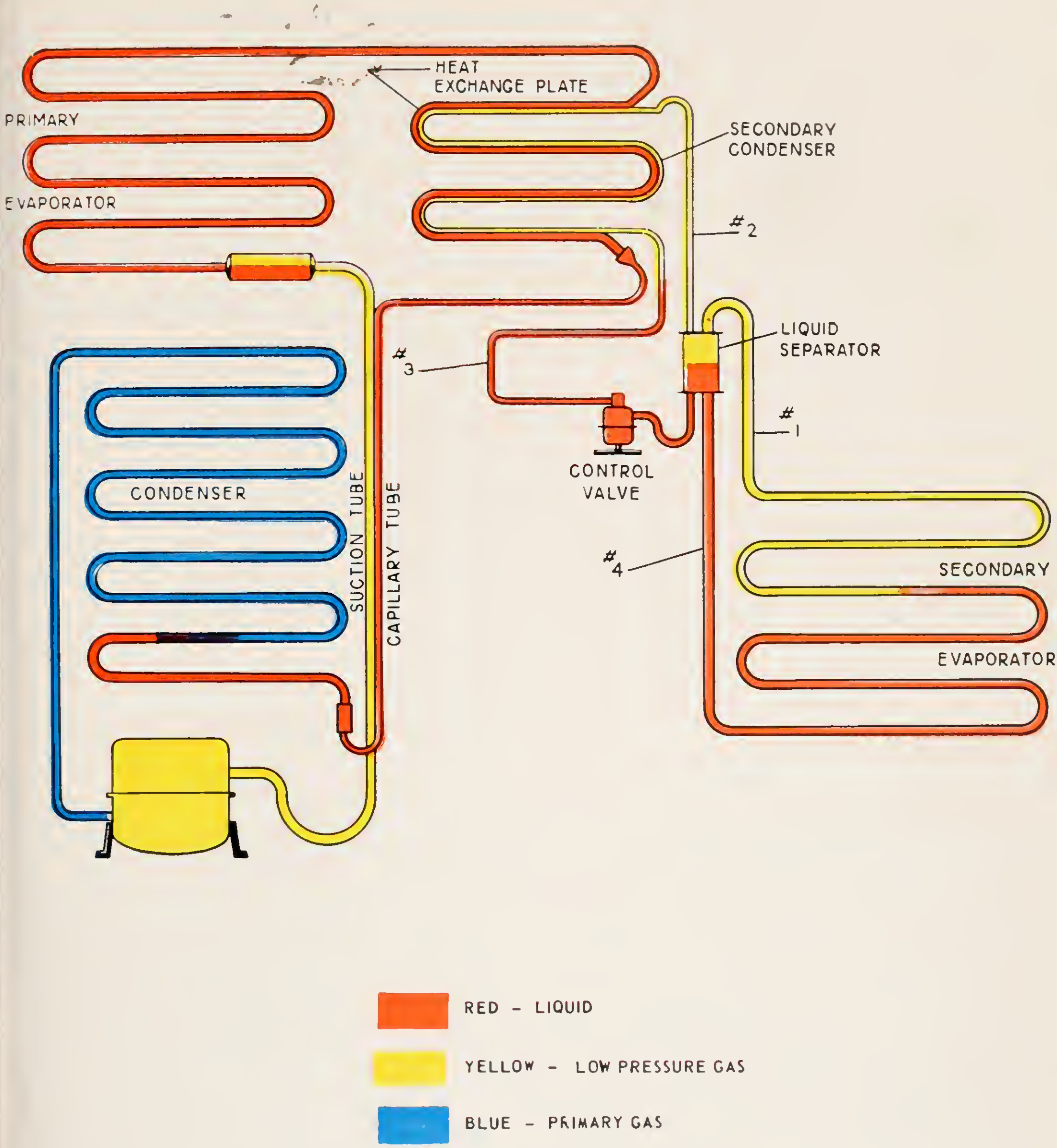
A diagram of the cycle used in a cabinet which uses a frozen foods cooling coil and the fresh foods portion cooled by spilled air is shown in Figure 16-8. The condenser (2) is the static type made of tubing with wire heat dissipator fastened to it. The condenser is mounted on the back of the cabinet. The capillary tube (3) and the suction line (6) are run together. The accumulator (5) is mounted on the cooling unit. The capillary tube is fastned to the cooling coil at (4).

A refrigerator cycle with the fresh foods cooling coil and the frozen foods cooling coils connected in series is shown in Figure 16-9. The main refrigerant control is a capillary tube (4)

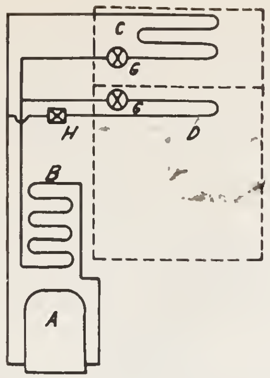


16-5. In this refrigerator a single condensing unit is used; however, a secondary refrigerant in a closed system picks up heat in the refrigerator cabinet and gives it up to the frozen foods compartment coil. A. Motor-compressor; B. Condenser; C. Low temperature cooling coil; D. High humidity cooling coil; F. Secondary condenser.

and the refrigerant is fed to the fresh foods coil first. The pressure in this coil is kept higher than the pressure in the frozen foods coil by the resistance of the restrictor. The accumulator is shown at (7), the suction line at (8), the condenser at (3), and the discharge line from the compressor at (2). A special condenser (1) is located near the compressor to furnish heat to evaporate the



16-6. A refrigerating cycle that has a secondary cooling system equipped with a pressure operated temperature valve. 1. Gaseous refrigerant. 2. Dry gaseous refrigerant. 3. Liquid refrigerant. 4. Liquid refrigerant in the cooling coil. When the cooling temperature rises, the control valve responds to the pressure rise and will open to allow more refrigerant to enter the cooling coil.
(Gibson Refrigerator Co.)



16-7. In this refrigerator a two-temperature valve on the refrigerator coil (highest temperature) provides the two temperatures required. A. Motor Compressor; B. Condenser; C. Low temperature cooling coil; D. High humidity cooling coil; G. Refrigerant controls; H. Two-temperature valve.

defrost water drained from the fresh foods cooling coil.

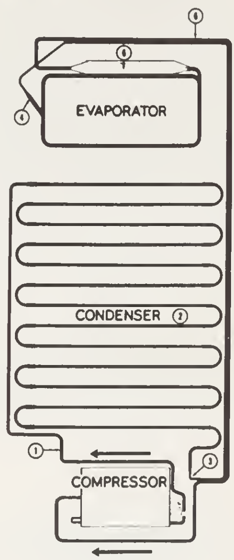
A clever refrigerating cycle for a cabinet with a fresh foods cooling coil and a frozen foods coil is shown in Figure 16-10.

The discharge gas from the compressor is first passed through a small condenser located in a flat position in the base of the cabinet. The heat from this condenser evaporates the drain water from the fresh foods cooling coil. The gas is then completely condensed in a static condenser mounted on the back of the refrigerator. A capillary tube then delivers reduced pressure liquid to the fresh foods cooling coil. A weighted valve keeps the pressure in the fresh foods evaporator higher than the pressure in the ice freezing shelf. An injector then delivers the remaining liquid refrigerant into the frozen foods cooling coil. Note that both ends of the frozen foods cooling coil are connected to the header or accumulator. The injector forces the liquid around and around the frozen foods cooling coil until it is all evaporated. The evaporated refrigerant then returns to the compressor by way of the suction line.

16-3. REFRIGERANT CONTROLS

Hermetic systems quite generally use either the high side float or the capillary tube refrigerant controls or a combination of both. These controls have proven very successful although both require a carefully measured refrigerant charge.

The design, construction, and operation of these refrigerant controls is



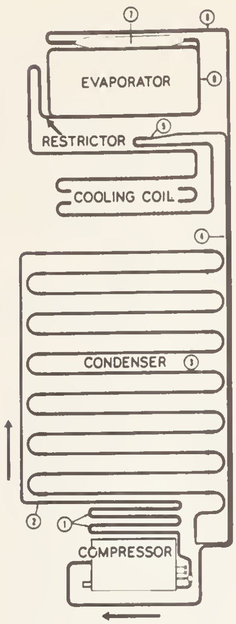
16-8. A refrigeration cycle using a shell type evaporator, (3 and 3) a capillary tube, (2) a wire type static condenser, (5) accumulator (6) suction line. (Hotpoint Co.)

explained in Chapter 5.

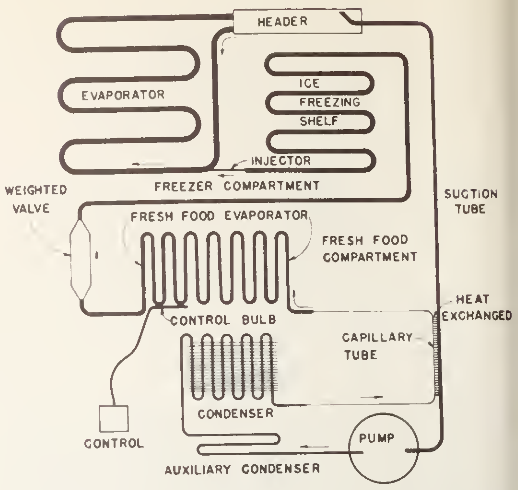
16-4. HERMETIC COMPRESSOR DESIGNS

The development of hermetic compressors and their manufacture has required some of the most accurate craftsmanship our industry has produced. Parts are being fitted to micro-accuracies under production conditions. There are two types of compressors in popular use, namely:

a. The reciprocating compressor.
b. The rotary compressor.



16-9. A refrigerating cycle with the fresh foods cooling and the freezer cooling coil connected in series. (1) defrost water evaporator (2) discharge line (3) condenser (4) capillary tube (5) cooling coil connection (6) cooling coil (7) accumulator (8) suction line. The restrictor keeps the fresh foods coil at a higher pressure than the freezer coil.
(Hotpoint Co.)



16-10. A schematic diagram of a cycle with the fresh foods cooling coil and the freezer cooling coil in series and with a weight valve maintaining the pressure difference. Note the auxiliary condenser for evaporating defrost water. The injector keeps the liquid refrigerant circulating in the freezer evaporator.
(General Electric Co.)

Both are being produced in great quantity and are giving very quiet and efficient service.

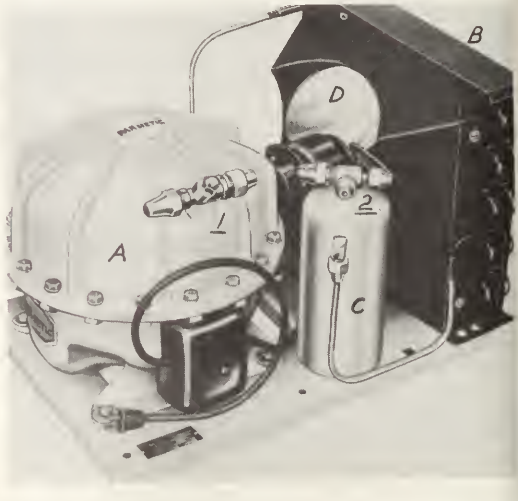
These compressors have been explained in detail in Chapter 4.

16-5. CONDENSER DESIGN

There are several types of condensers being used in the hermetic designs:

a. Fan cooled finned type (forced convection).
b. Natural convection finned condenser.
c. Natural convection plate condenser.

The use of a fan requires a separate electric motor. The condenser is usually made of copper tubing and copper fins, tin dipped. A shroud is put over the fan and condenser to increase the control of air flow over the condenser, Fig. 16-11. Some companies install



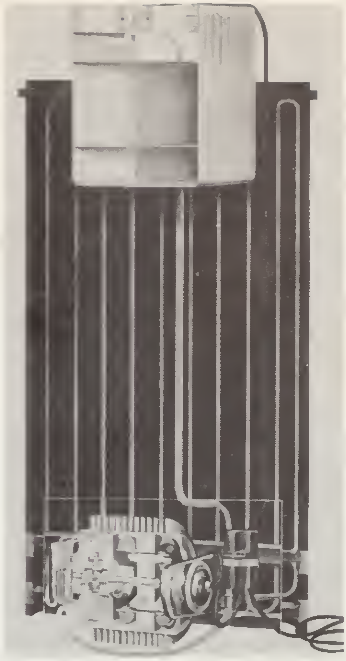
16-11. A serviceable hermetic condensing unit. A. Motor-compressor; B. Shrouded condenser; C. Liquid receiver; D. Fan. 1. Suction service valve, 2. Liquid receiver service valve.
(Lynch Corp.)

air-in and air-out ducts to improve the condenser cooling and also to decrease the noise. These ducts are usually made of some acoustic (noise absorbing substance) such as felt, cardboard, etc.

It is very important that these ducts remain intact and that the air flow does not become restricted.

Condensers that do not use a fan to provide forced air are sometimes called static condensers, Fig. 16-12.

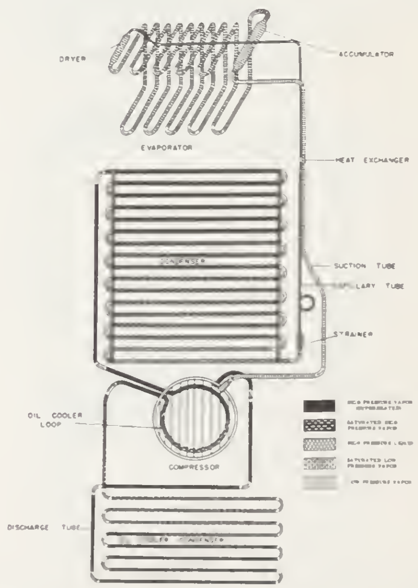
16-12. A natural convection finned condenser. This unit has two service valves. The condenser is inclined to permit cool air to contact all parts of the condenser. (Tecumseh Products Co.)



16-13. A plate type hermetic system condenser. Note that the tubing is attached to a large sheet of metal for maximum air contact and "chimney effect." (General Electric Co.)

The plate condenser is the easiest of the three to manufacture and it is also easiest to clean externally. However, it is more bulky in order to have sufficient cooling area and takes up more space than the other two types, Fig. 16-13.

Figure 16-14 illustrates a cycle diagram in which the condenser is in two parts. The high pressure gas from the compressor goes first through the oil cooler condenser. The heat from this condenser is used to evaporate the condensate from the box on the defrost cycle. The saturated high pressure vapor passes through a loop in the compressor to cool the oil, it is then cooled in the condenser and flows through the capillary tube and to the evaporator.

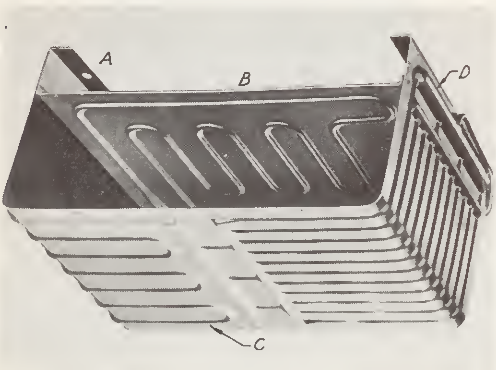


16-14. A domestic cycle diagram in which the condenser is in two parts. Heat from the oil cooler condenser is used to evaporate defrost condensate. (Crosley Div., Avco Mfg. Co.)

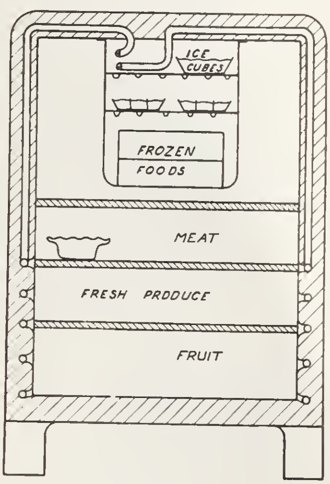
16-6. COOLING COILS

There are many cooling coil designs in use. The shape of the cooling coil depends to a great extent on the use of the coil, the space allotted to the coil, and the type of refrigerant control.

These cooling coils may be made of copper, aluminum or stainless steel with the latter two becoming increasingly popular. There has been a gradual change in design from coils made of tubing wrapped around metal sleeves that held ice cube trays, to stamped or formed sections which incorporate the tubes, the collector headers and the shelves all in one piece, Figure 16-15.



16-15. A one piece type of cooling coil in which the tubes, beaders and shelves are formed in a single piece. A. Mounting bracket; B. Shelf; C. Refrigerant passage; D. Accumulator.
(Houdaille-Hershey Corp.)



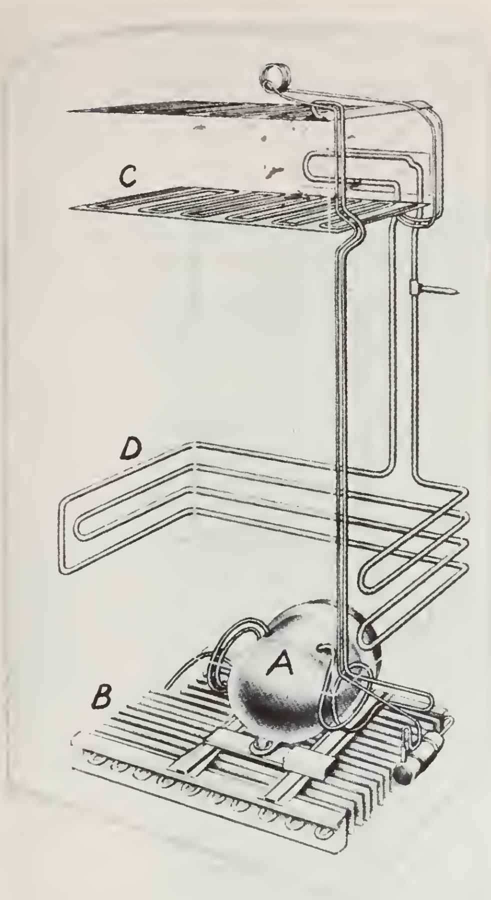
16-16. A modern refrigerator design which provides ice cube freezing and storage, frozen foods space and high humidity cold storage space for perishable foods.

The ideal domestic refrigerator should quickly freeze ice cubes; it should freeze and provide storage for frozen foods, and it should provide a non-drying (high humidity) refrigerated space for storage of open and perishable foods, Figure 16-16.

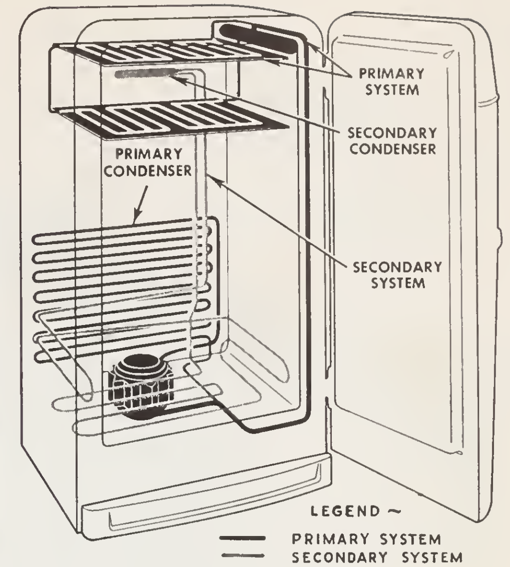
To accomplish this triple function, some companies use one cooling coil held to a low temperature which makes ice cubes and keeps frozen foods. Through its low temperature and its small area exposed to the large cabinet volume, it also keeps the cabinet temperature very nearly correct; however, it has the disadvantage of drying the foods quite rapidly. This results in rapid frosting of the cooling coils as well as providing a low humidity in the cabinet.

Other manufacturers have provided two compartments in the cabinets, one for ice cubes and frozen foods and one compartment for fresh produce. This design is more expensive since it means using two cooling coils, one equipped with a two temperature valve, a secondary cooling system, an overflow coil with restriction between the two coils or using two condensing units.

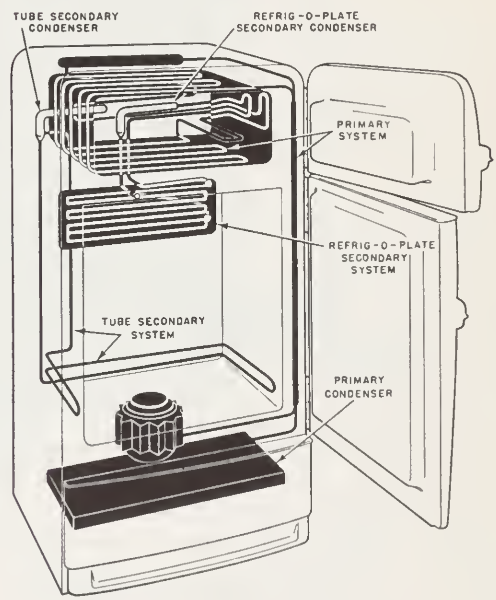
One of the simplest and most effective solutions is to use a secondary refrigerant in a separate cooling coil and condenser system sealed from the regular system, Figure 16-17. This secondary system uses the cooling coil of the first system to cool its condenser and it has its cooling coil attached to the outside of the inner lining of the cabinet or as a finned coil, located in the rear of the inside of the cabinet. One manufacturer calls the former arrangement the "Cold



16-17. Diagram of a secondary refrigeration circuit. The cooling coil in the freezing compartment (primary circuit) contacts the condenser coil of the secondary refrigeration on temperature difference only. Both the primary and secondary systems are charged with the same kind of refrigerant. A. Motor-compressor; B. Condenser; C. Freezer cooling coil; D. Secondary cooling coil.



16-18. Diagram of a refrigeration circuit which uses a secondary refrigerant for cooling the normal storage compartment.
(Frigidaire Div., General Motors Corp.)



16-19. Refrigeration circuits using two secondary refrigerant systems. A control on one of the secondary systems gives the housewife an opportunity to defrost and remove the moisture from one (Refrig-o-plate) of the secondary system.
(Frigidaire Div., General Motors Corp.)

Wall," Figure 16-18 and Figure 16-19. Others use a large surface coil (finned) as the cooling coil for the high humidity, 35 F. to 45 F. portion of the cabinet.

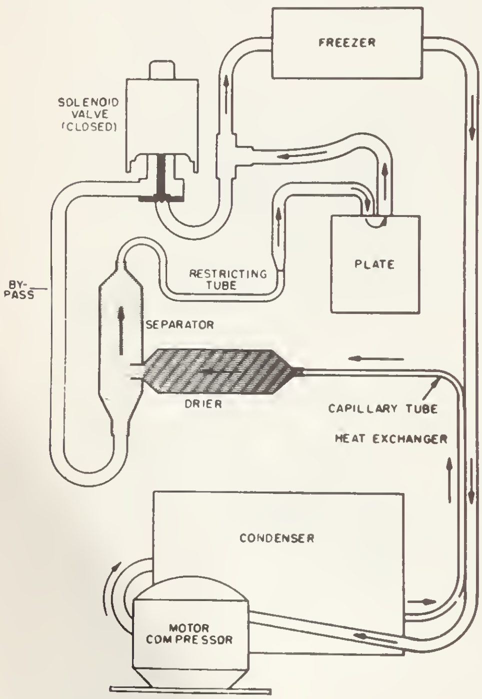
A two-temperature system that uses a solenoid valve to produce the two temperatures is shown in Figure 16-20. When the thermostat in the food compartment calls for more cooling the solenoid valve closes and the refrigerant passes the plate coil before it reaches the freezer coil. When the food

compartment is cool enough, the solenoid valve is energized and opens, Figure 16-21. The refrigerant will now by-pass the plate coil due to ease of flow. The thermostat operated by the freezer coil cycles the motor-compressor unit.

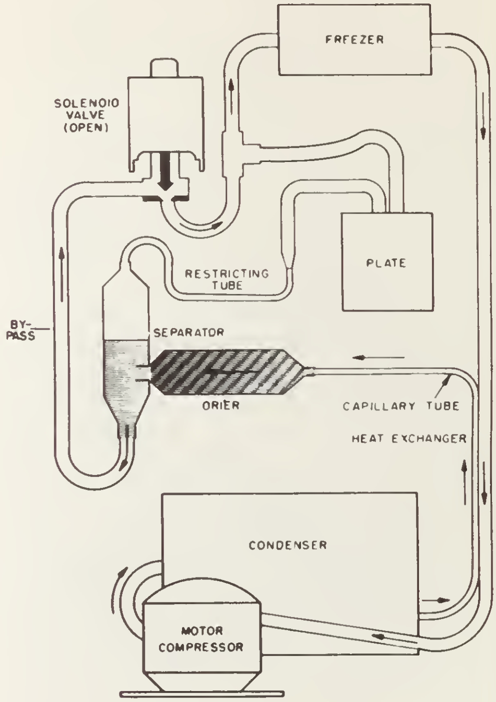
16-7. TUBING

The trend is to use soft soldered and silver brazed tubing in all the later domestic units. This tubing is attached permanently to the cooling unit and condensing unit and necessitates removing the complete mechanism from the cabinet at one time as the soldered joints are inconvenient to separate. Usually the liquid line and suction line are permanently fastened together.

Copper or steel tubing is brazed to the condenser and compressor motor dome as these parts are of copper or steel. Many cooling coils are made of aluminum and attachments to them cannot be silver brazed. The manufacturer, in some cases, flash welds (a resistance welding operation) a short length of copper tubing to the aluminum tubing connection of the aluminum coil. This copper tubing must be left connected to the aluminum cooling coil during service operations in order that it may be easily reconnected into the system after the service operation has been completed.



16-20. A refrigeration cycle that uses a solenoid by-pass to control the plate temperature. The valve is closed and the plate is being cooled. (Philco Corp.)

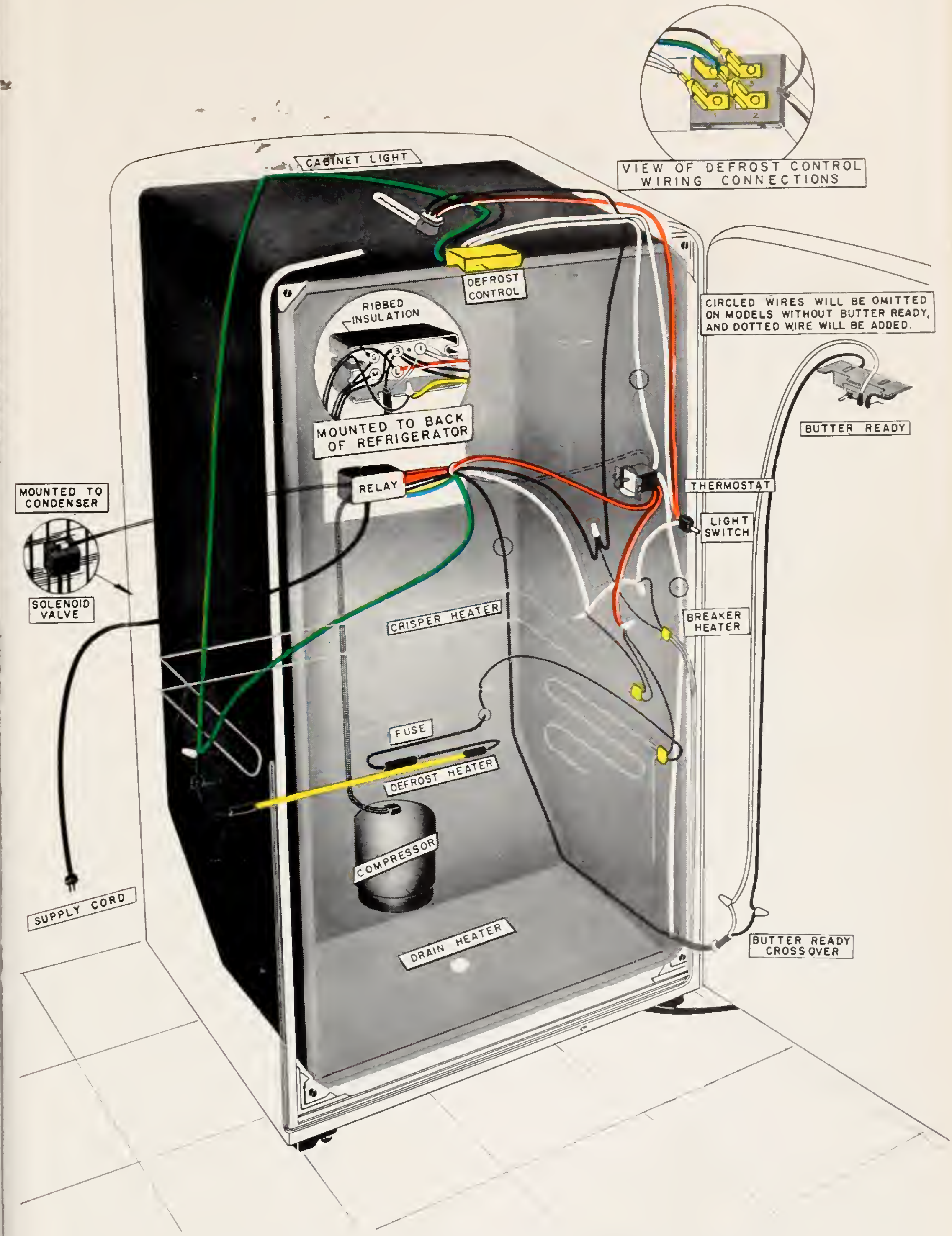


16-21. A cycle that uses a solenoid valve to control the plate temperature. The valve is open and the refrigerant is by-passing the plate coil which therefore is not being refrigerated. (Philco Corp.)

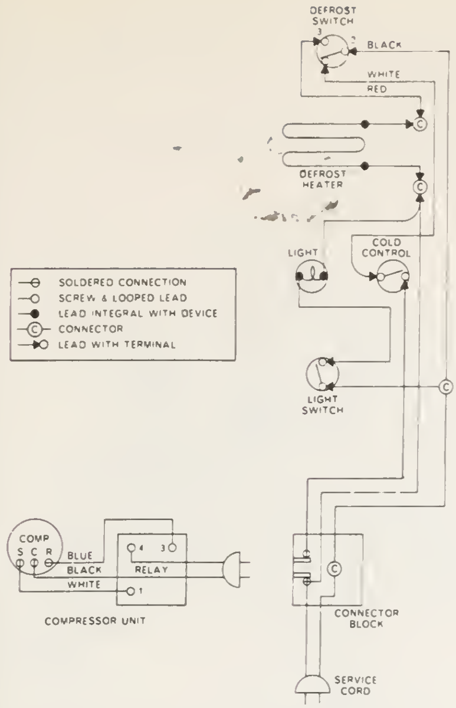
16-8. ELECTRICAL CIRCUITS

The electrical circuits of the hermetic mechanisms are very much similar. See Figure 16-22. The main portions of the electrical system are:

a. Motor



16-22. The arrangement of the electrical wiring in a refrigerator cabinet. (Seeger Refrigerator Co.)



16-23. A wiring diagram for a conventional hermetic refrigerator which has an electrical heating coil for defrost.
(Hotpoint Co.)

b. Motor control
c. Starting switch (Relays)
d. Cabinet light and switch

Other devices used frequently are:

a. Condenser motor fan
b. Ultra-violet ray lamp
c. Defrosting heater
d. Butter warmer

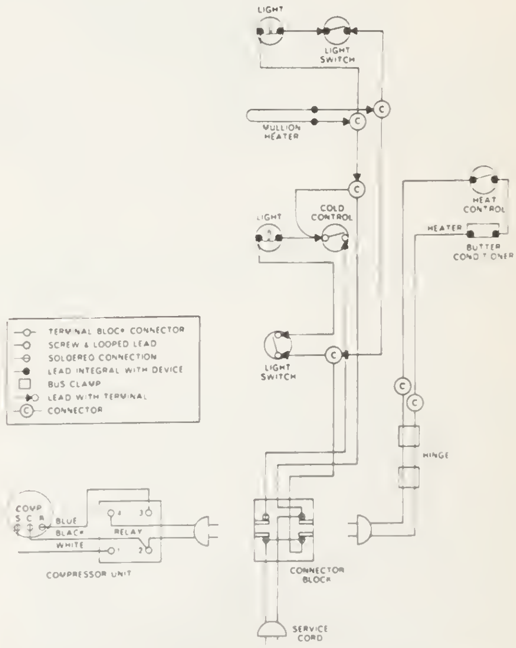
Power to the refrigerator is obtained through a rubber covered extension cord usually of No. 14 stranded wire. This cord is connected to a junction box mounted on the condensing unit. This junction box also often houses the starting relay, Figure 16-23.

A three-wire cord extends from the junction box to the refrigerator cabinet. These three wires (white, black and red or green) are used for the cabinet light and the motor control (thermostat). It is general practice that the black wire is the live wire and goes from the plug up to the motor control. The white wire returns from the motor control, down through the junction box, into the relay and then into the motor. The third wire is red or green and carries the current from the light switch and back to the white wire of the extension cord, Figure 16-24.

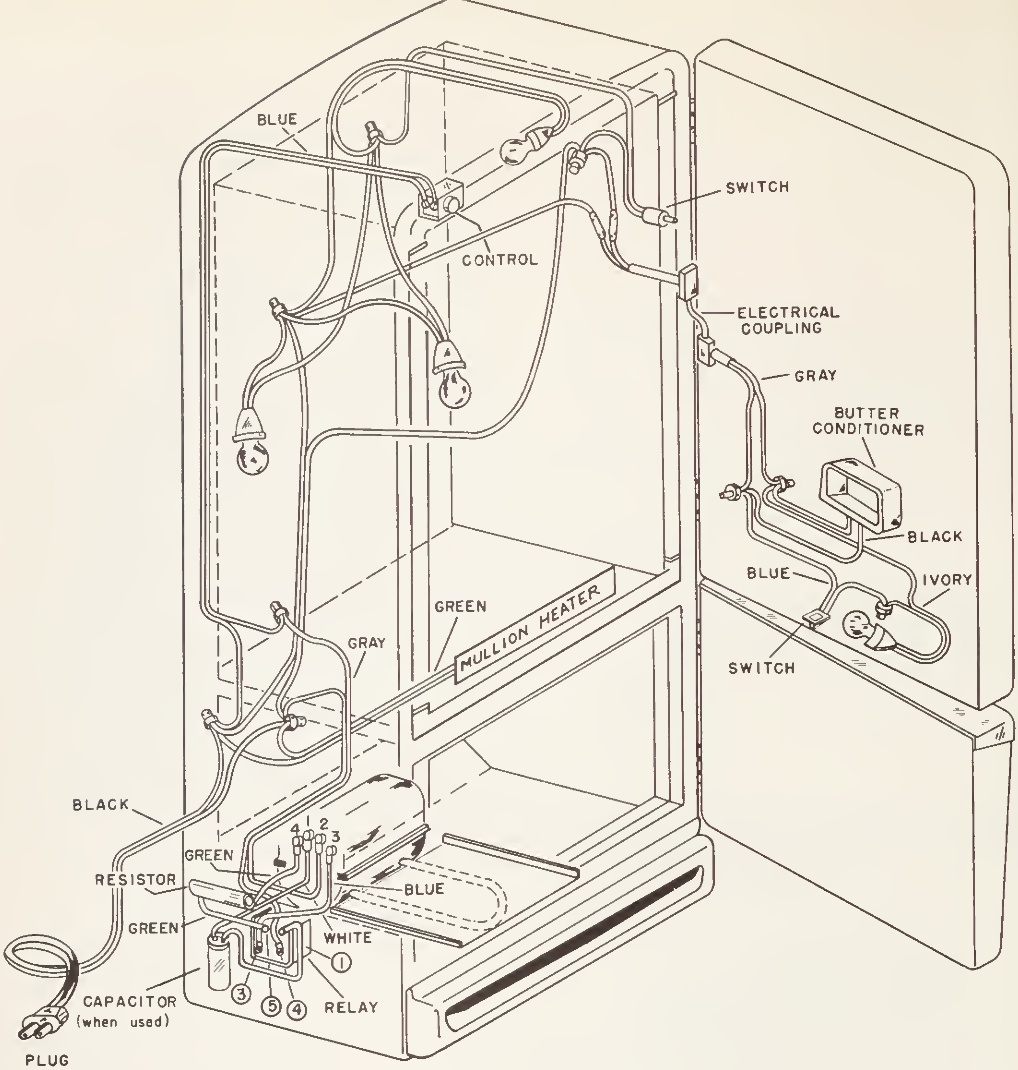
Most of the electrical connectors are mechanical in the later models. Even the terminals on the end of the wires are mechanically attached to the wires. Stranded wires should never be wrapped around terminal posts. Always use wire terminals of some kind.

The wiring of a refrigerator that uses a four terminal motor-compressor unit, a butter conditioner, a mullion heater, cabinet lights and a thermostat operated from the fresh foods cooling coil is shown in Figure 16-25.

A definite color code is followed in the wiring. The black wire feed in from the wall plug or the extension cord is



16-24. A wiring diagram for a hermetic refrigerator which incorporates a heating coil to keep the frozen foods door joint from sweating.
(Hotpoint Co.)



16-25. A pictorial drawing of the wiring in a refrigerator. Note the mechanical connections used. The number and color code is similar to those used in all refrigerators. The compressor motor has four terminals as it is a 3400 r.p.m. motor and uses an auxiliary winding.
(General Electric Co.)

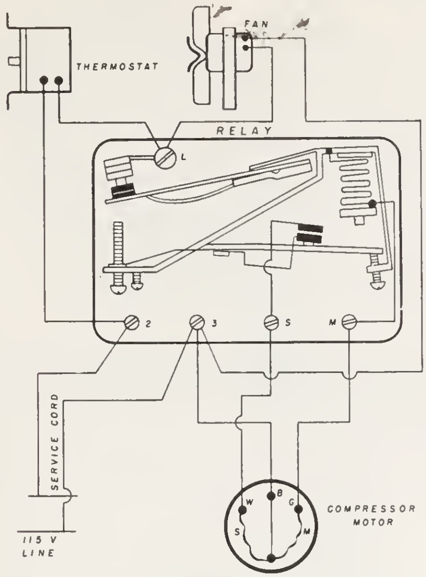
the hot wire. The current is fed along three separate wires from this wire. One wire to the thermostat, one wire to the million heater, and one wire to the lights and butter conditioner. The motor-compressor unit operates at 3600 r.p.m. and has three motor windings necessitating four (4) terminals. The capacitor is used in the larger units while the resistor is used on all those models having the third or auxiliary winding.

16-9. MAIN ELECTRICAL CIRCUITS

The main wiring circuit of a refrigerator comprises a plug-in cord, a thermostat, a light, a light switch, a relay, and a motor, Fig. 16-26.

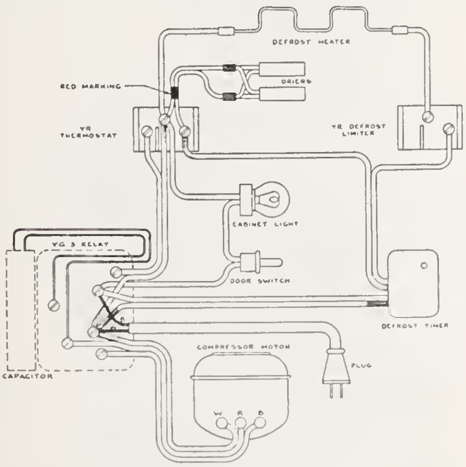
The relay is usually the junction box for all the wires. The thermostat is electrically located in series with the motor, the relay and the power-in plug. The light switch and light are located in

parallel with the motor. These connections mean that the cabinet light can operate even though the system is not running. The light switch is a spring loaded switch mounted in the cabinet



16-26. A wiring diagram of a hermetic system showing a condenser fan electrically connected into the circuit. (Kelvinator Div., American Motors Corp.)

door jam and the switch spring closes the switch as the door opens.



16-27. A wiring diagram using an electrical defrost, defrost timer and drier to prevent sweating. (Frigidaire Div., General Motors Corp.)

A wiring diagram showing the more popular parts of the electrical system are shown in Figure 16-27.

16-10. ELECTRICAL CIRCUIT ACCESSORIES

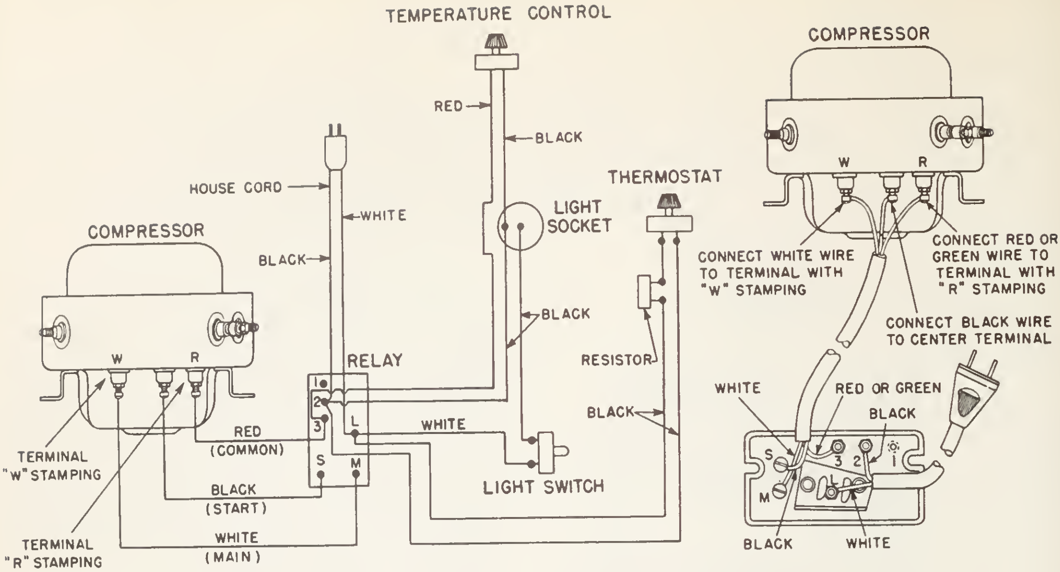
Many refrigerators in addition to the devices listed above have other electrical accessories. Some have motor driven fans to help cool the condensers. The fan motor is connected in series with the thermostat and in parallel with the compressor motor. Therefore, all the electricity used by the compressor motor and the fan motor passes through the thermostat switch.

Some refrigerators have small heating elements in the butter compartments. These small heating elements keep the butter a few degrees above the normal 35-45 F. compartment temperature. The resistance is connected in the system in parallel with the other units. It has its own thermostat, Figure 16-28.

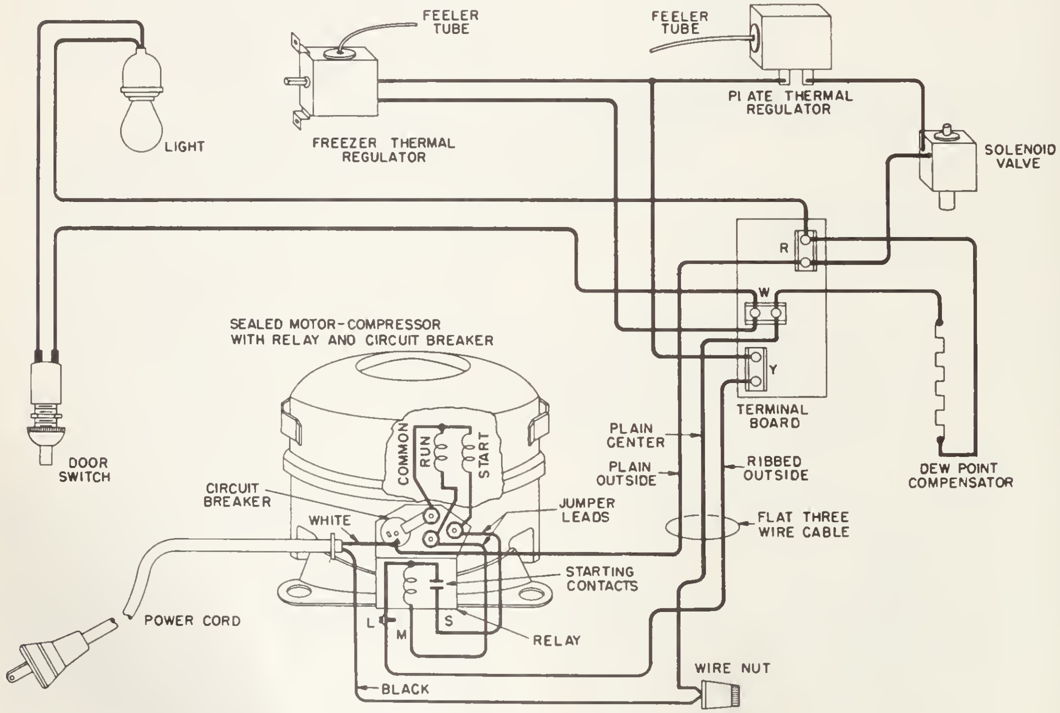
Occasionally the breaker strips around the freezer compartment door will sweat or frost. Formerly double rows of gaskets were used to minimize this condition, but at present very small electrical resistance wires are mounted in back of the breaker strips to eliminate this condition. Figure 16-29 illustrates a wiring diagram of a domestic unit. It has a dew point compensator circuit shown on the right.

Some refrigerators have a very small heating element mounted inside the cabinet liner near the cooling coil of the non-freezer section of the box. This heating element operates during the time the unit is not running and prevents ice formation on the cabinet liner and also acts to cycle the unit when the regular food compartment is not used frequently, Figure 16-30.

Ultra-violet ray lights are used in some refrigerators as an air purifying agent. These lights operate from a

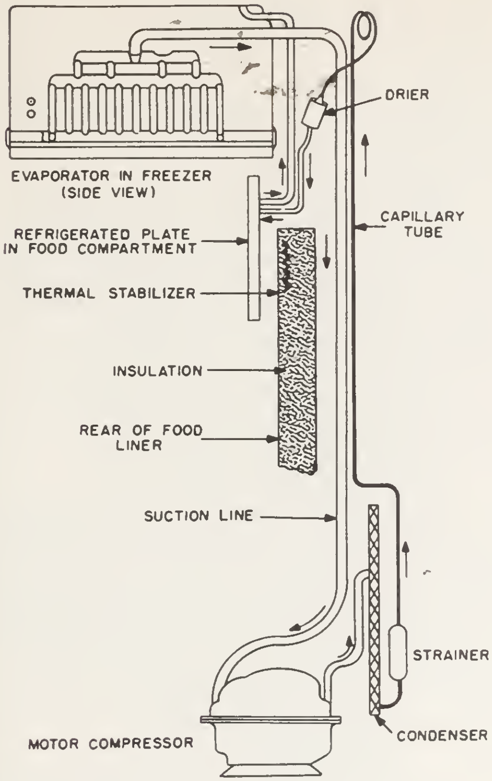


16-28. Wiring diagram of a hermetic system showing the electrical connections for such items as motor relay, cabinet light, and butter conditioner and thermostat. It also shows the connections between the starting relay and the motor.
(Crosley Div., Avco Mfg. Co.)



16-29. The wiring diagram of a two compartment domestic refrigerator. Note the freezer thermal regulator for cycling the unit, the plate thermal regulator for controlling the solenoid, and the dew point compensator for warming the breaker strip.
(Philco Corp.)

transformer. The electrical circuit is in parallel with the other main units of the system.



16-30. A two compartment refrigerator having a thermal stabilizer heating element mounted back of the plate cooling coil to insure against frosting and to cycle the unit during long no-use periods.
(Philco Corp.)

16-31. A defrosting clock which can be connected to the power circuit of any domestic refrigerator.
(Automatic Controls Corp.)

16-11. DEFROSTING SYSTEMS

The method of defrosting domestic refrigerators has improved considerably in the past few years. In the beginning defrosting was accomplished by shutting off the system until all the frost melted and then turning the unit on again manually or automatically. Trays caught the melted frost. These trays were emptied manually.

Since the development of frozen food compartments in domestic refrigerators a better way had to be developed for defrosting. The new systems defrost the coils quickly to prevent raising the temperature of the frozen foods, and the defrost water is removed from the cabinet automatically.

There are five principal ways in which the automatic defrost interval is determined. The mechanisms for each are different. These methods are:

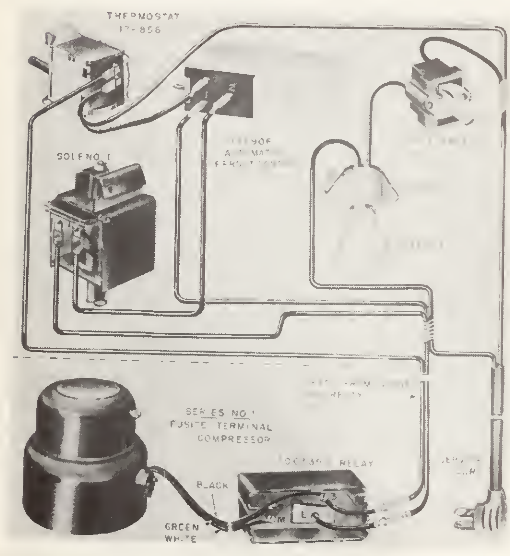
1. Daily by clock timing.
2. Accumulated running time of the condensing unit.
3. Accumulated door open time.
4. Counted number of door openings.
5. Operation on a defrosting cycle.

Daily by clock timing is the simplest and most common. In this system an electric clock mechanism is wired into the electric circuit to defrost the refrigerator daily at a time to which the clock is set, Fig. 16-31. This time is usually set sometime after midnight. It may be set to suit the wishes of the owner.

Accumulated running time of the condensing unit defrosting is timed by leaving an electric clock mechanism connected in parallel with the compressor motor. The clock will run all of the time that the compressor is operating. The clock mechanism is set to operate the automatic defrost after a certain number of hours of operation of the condensing unit (usually about six

hours). This interval of defrosting is adjustable to accomodate various conditions of use of the refrigerator.

Accumulated door open time also times the defrost interval through an electric clock mechanism which operates the automatic defrost after a total number of minutes that the refrigerator door has stood open. The principle of this timing is based on the fact that each time the refrigerator door is opened the cold air in the cabinet spills out. Part of the moisture in this air has been deposited on the cooling coil and as the door is opened fresh moisture laden air enters and will be deposited on the cooling coil. Frequent and prolonged opening of the cabinet door will hasten frost accumulation on the cooling coil. This defrost timing device therefore, provides automatic defrosting on the basis of cabinet use.



16-32. Wiring diagram which shows circuits and controls for a hot gas type of automatic defrost system. (Kelvinator Div., American Motors Corp.)

The counted number of door openings defrost interval is based on the same principle as the accumulated door open time. Instead of using a clock mechanism, a ratchet mechanism on the door operates the automatic defrost system. After a certain number of door openings (usually about 60) the automatic defrost device will be brought into operation.

Most automatic defrost systems control the length of the defrost time by a thermostat attached to the cooling coil. Automatic defrosting is accomplished by stopping refrigeration and rapidly heating the cooling coil.

The two sources of heat used to quickly defrost the coils are:

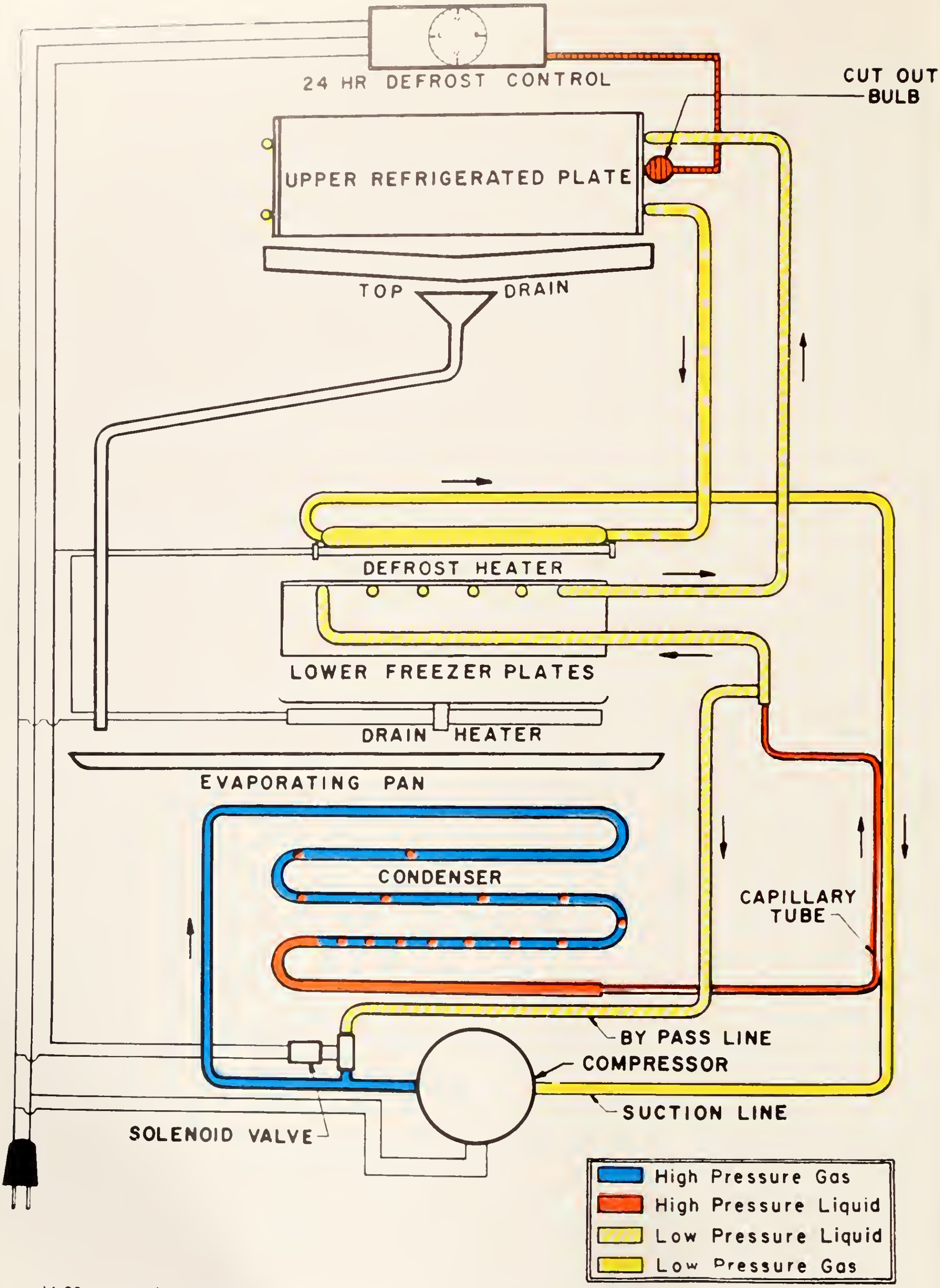
1. Hot condenser gas.
2. Electrical heating coils.

Primarily, all of the automatic defrost systems depend on electrical controls for their operation. Figure 16-32 shows a hermetic wiring diagram with the conventional automatic defrost controls connected into the circuits.

16-12. HOT GAS DEFROST SYSTEMS

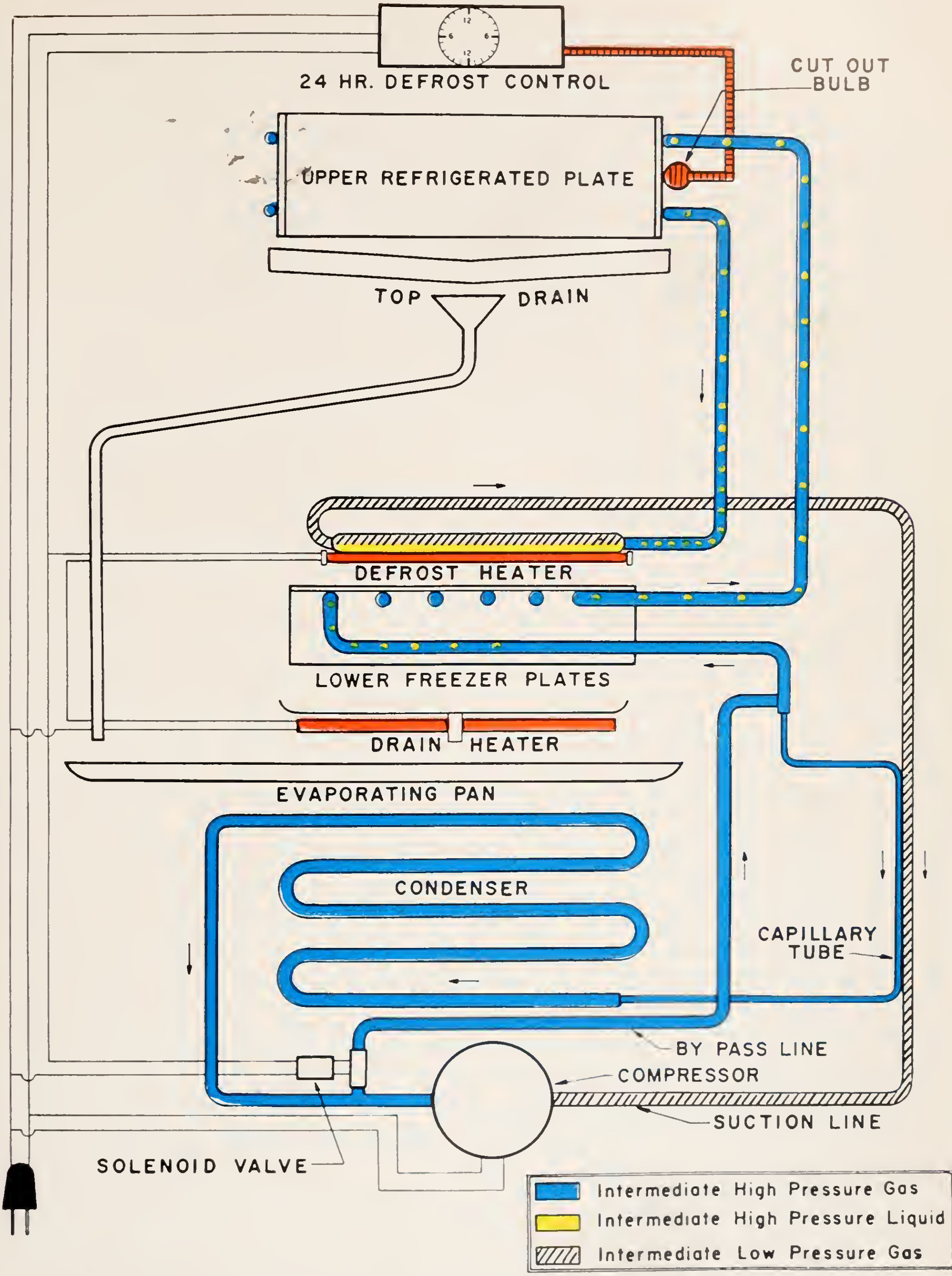
To defrost the cooling coil with hot gas, the hot gas coming from the compressor is piped into the cooling coil where it circulates and melts the frost from within. The gas then returns to the compressor.

The mechanism consists of a solenoid valve located in a by-pass line running from the outlet of the compressor to the cooling coil at the capillary tube end, Figure 16-33. This illustration shows an automatic defrost system on the refrigerating cycle. The liquid refrigerant flows through the lower frozen plates on its way to the upper refrigerated plate. Heat is first absorbed from the freezer compartment and any extra liquid refrigerant passes upward to cool the food storage area. The lubricating oil has the ability to absorb refrigerant in increasing



16-33. A cycle diagram and wiring of a hermetic system using "hot gas" automatic defrost. This illustation shows the refrigerating cycle. Note the drain tube and the condensate evaporator pass over the condenser.

(Seeger Refrigerator Co.)

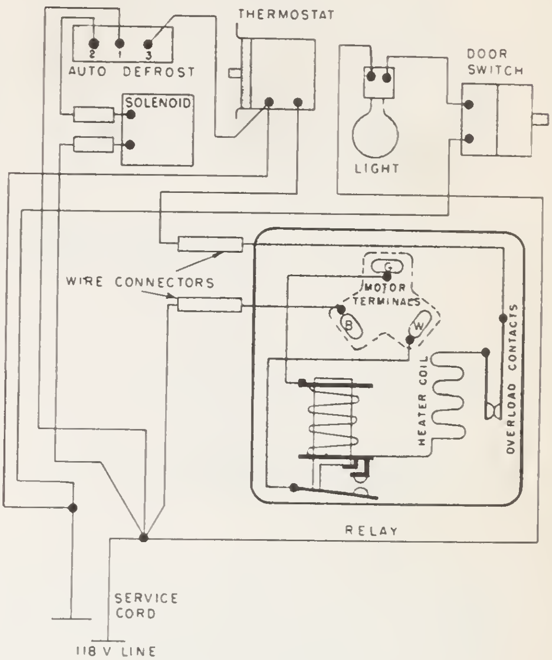


16-34. The defrost cycle diagram for a "hot gas" and electric heat automatic defrost. The defrost control has opened the solenoid valve by passing hot gas to the refrigerated plates and turns on the compressor which rapidly warms up both coils.

(Seeger Refrigerator Co.)

amounts as oil temperatures are reduced and release refrigerant as oil temperatures are increased. On the "off" cycle, the compressor and the oil in it cool. The cool oil will absorb some of the refrigerant in the unit, leaving an insufficient amount of refrigerant to refrigerate both coils completely. At the beginning of the "on" cycle, all of the available refrigerant will be evaporated in the lower freezer plates and little or no refrigerant will reach the upper coils. During this period, frost on the upper plate may melt. After the compressor has operated for a few minutes and has warmed up, the oil will release the absorbed refrigerant and this additional refrigerant will pass to the upper refrigerated plate. The thermostat contact bulb is attached to the upper refrigerated plate so the compressor will continue to operate until the upper plate has been completely refrigerated. The freezer compartment will continue to be refrigerated during the entire "on" cycle while the food storage space will receive cooling during only a part of the cycle. In this manner the proper food space is maintained at a satisfactory low temperature automtically.

The automatic defrost control places the mechanism on the defrost cycle once each 24 hours. The defrost cycle is shortened by the use of two electric heaters, Figure 16-34. On the defrost cycle, a solenoid valve opens and directs the flow of warm refrigerant gas from the compressor direct to the lower freezer plates. This hot gas helps melt the frost which has accumulated on the evaporator coils. Some of the refrigerant will be condensed but to prevent the liquid refrigerant from being returned to the compressor and to add to the heat of the refrigerant, an electric heater element is used to boil the refrigerant. The warm gas helps in defrosting the coils and is then drawn back to the compressor, then the suction line (gray on the diagram). A second electric heater which is mounted on the bottom of the freezer compartment is also turned on during the defrost cycle to prevent any freeze-up of the drain at

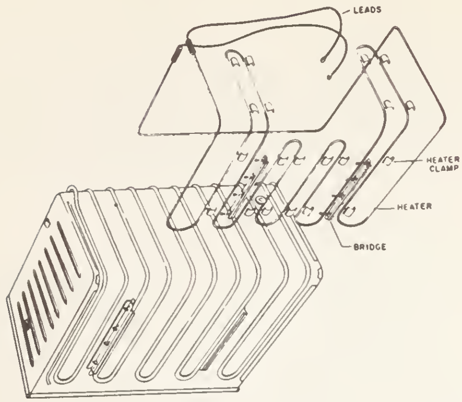


16-35. The wiring diagram for a hermetic system which has a semi-automatic defrost.
(Kelvinator Div., American Motors Corp.)

the bottom of the compartment and to remove any frost that may have formed on the interior of the walls of the freezer. The defrost cycle continues until the temperature of the defrost control bulb rises to approximately 40 F. or for one hour--which ever occurs first.

The defrost control will return the system to normal operation after the defrost interval.

Some semi-automatic systems require opening the solenoid with a manual electric switch. When the defrost is complete, a slight rise in temperature activates a sensitive bulb which returns the system to normal operation. Figure 16-35 shows the



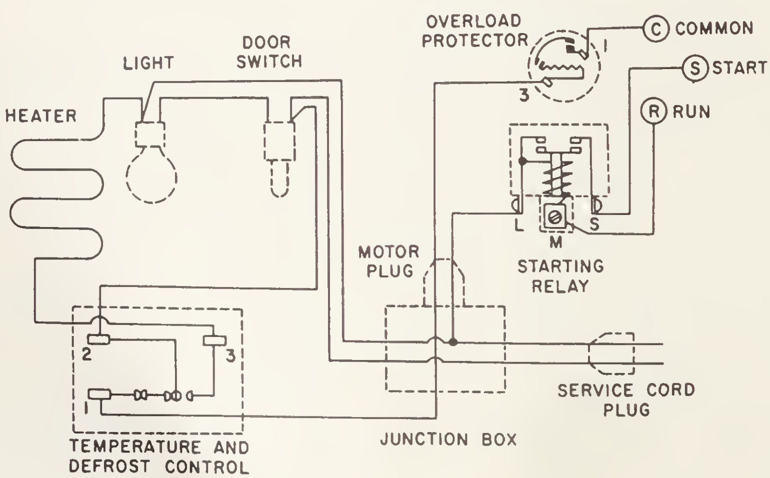
16-36. An electrical heating unit (exploded view) applied to a cooling coil and used to provide automatic defrost facilities.
(Crosley Div., Avco Mfg. Corp.)

wiring diagram for this type of automatic defrost.

16-13. ELECTRIC HEATER DEFROST SYSTEM

To defrost the unit with electrical heating elements requires installing heating coils or electrical resistance wires beneath those parts of the coils needing defrosting, Figure 16-36. These electrical heating elements are well insulated, the circuit is usually equipped with a fuse. Some circuits have a safety thermostat which will open the circuit in case the temperature rise is too great. Figure 16-37 shows the wiring circuit of an electrical defrost system which is started by pressing a push button and that automatically returns to normal operation. Figure 16-38 is another semi-automatic electrical defrosting system.

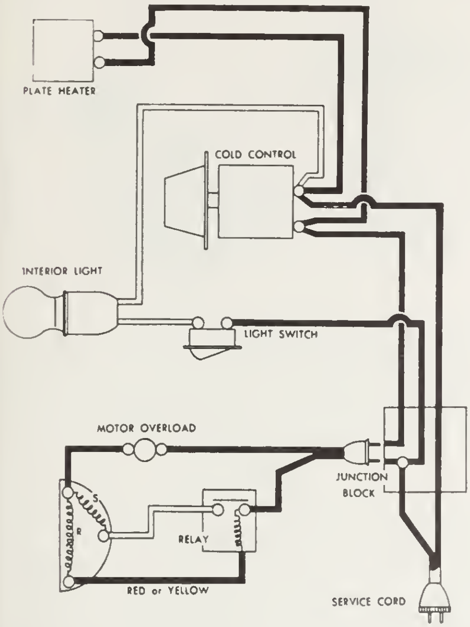
The resistance wires proper are placed to melt the frost from the coils in a minimum of time. These coils are rated at 400 watts and up. Some units are automatically shut off during the defrost cycle and a thermostat returns the unit to normal operation after the coil is defrosted. The wiring diagram of a full automatic system is shown in Figure 16-39. Water formed is disposed of in several ways. Some systems run the defrost water down to a pan near the compressor-motor where the heat from the compressor evaporates it. Some units drain the water into a special tray and this tray must be periodically emptied. The drain pipe must have a



16-37. An electrical defrost system which is started by means of a push button and which automatically returns to its normal cycle. Note the overload protection for its motor-compressor and also note the amperage type relay.
(Franklin Mfg. Co.)

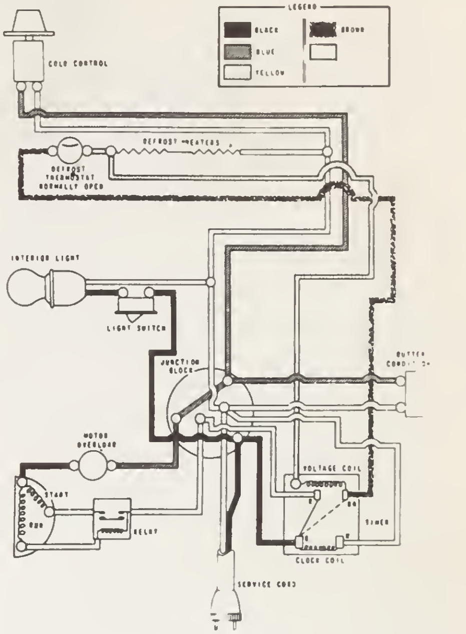
liquid trap.

One refrigerator uses a motor control which is controlled by a thermostat actuated by the fresh foods cooling coil. The freezer section cooling coil is in series with the fresh foods coil. The cycle of operation is shown in Figure 16-40. When the unit first starts at a fresh foods coil temperature of 375 F., the fresh foods coil still warms up a little but the freezer coil immediately starts to become colder (starts at 8 F.). As the unit runs the fresh foods coil temperature lowers quickly and the freezer coil

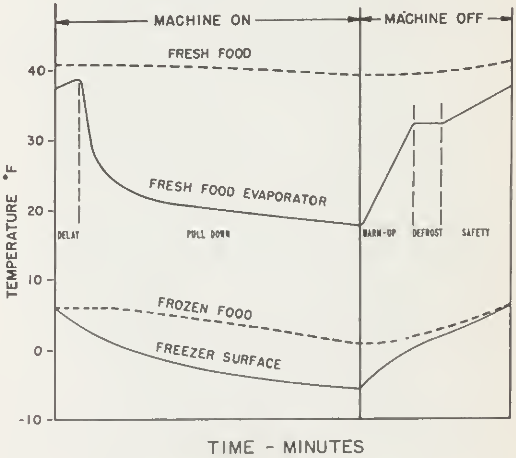


16-38. A wiring diagram of a hermetic system which uses an electrical resistance defrost unit that is turned on normally and which automatically returns to normal operation.
(Norge Sales Corp.)

slowly. At the end of the running cycle, the fresh foods evaporating open the thermostat at approximately 17.5 F. and the freezer coil has cooled to -5 F. During the off cycle the fresh foods coil must warm up past 32 F. (defrost temperature) and up to 37 F. before the unit starts running again. The dotted line at the top represents the fresh food temperature during the cycle. The bottom dotted line indicates the frozen food temperature during the cycle. The curves were obtained with the refrigerator operating in a 100 F. room.



16-39. A schematic diagram showing a full automatic defrost system using electrical heating elements.
(Norge Sales.Corp.)



16-40. A time-temperature graph of the cooling coil temperatures and the compartment temperatures of a two-door refrigerator. The thermostat is operated by the fresh food evaporator temperature.
(General Electric Corp.)

16-14. REVIEW QUESTIONS

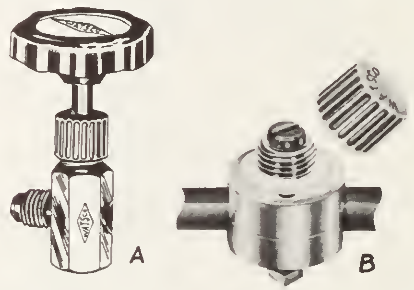
1. What is a hermetic refrigeration mechanism?
2. What is another name for a natural convection condenser?
3. How is copper tubing fastened to aluminum tubing?
4. What are some of the devices in the electrical circuit of a hermetic domestic refrigerator?
5. How is the temperature controlled in a butter compartment?
6. Why are systems being defrosted faster at the present time?
7. What is used to permit the flow of hot gas through the cooling coil for defrosting?
8. What is meant by a semi-automatic defrosting system?
9. Where are most of the refrigerant lines located in the latest model domestic refrigerators?
10. How is the defrost water removed after the defrost cycle?

16-41. The exterior of a heat pump motor compressor unit.
(Tecumseh Products Co.)

16-15. HERMETIC COMPRESSORS FOR HEAT PUMP INSTALLATIONS

The use of heat pumps for residential heating and cooling is increasing rapidly. Hermetic compressor units for heat pump use, have been developed in many designs, and in a wide range of sizes.

The hermetic compressor is ideal for such installation as it is simple to mount, and connect into the installation. Such compressors are equipped with service valves, suction and discharge



16-42. A service valve assembly for hermetic units. The bottom portion (B) fastens to the line by means of two small cap screws. The joints are sealed with synthetic rubber gaskets. The hand valve (A) that operates the tap is removable and therefore only one is needed by the service man.
(Watsco, Inc.)

mufflers and other special features which contribute to quiet reliable operation and long life. Fig. 16-41 illustrates a hermetic compressor designed for residential heat pump installation.

16-16. HERMETIC UNIT SERVICE VALVE

A means to connect gauges and charging cylinders to a hermetic system is shown in Fig. 16-42. The device has a removable service valve thus reducing the weight and strain on the tubing. Synthetic rubber gaskets seal the joints, and a needle point on the small screw pierces the tubing when the screw is turned in by the hand valve.

Chapter 17

SERVICING HERMETIC SYSTEMS

Hermetic units are made in various styles. The service procedure depends on the design. Hermetic units have been made since 1925.

Originally the hermetics were designed to fit on the top of the refrigerator cabinet (General Electric Monitor Top, Coldspot, Westinghouse, etc.). Following this design the units were made to fit into the back of the cabinet and the condensing unit was mounted in the base of the cabinet.

The latest designs generally have condensing units in the base and run the refrigerant lines just back of the cabinet door jam breaker strip. The cooling units are removed from the front of the refrigerator.

17-1. SERVICING HERMETIC UNITS

The servicing of hermetic refrigerator mechanisms depends to a great extent on the assembly method for the unit. If the unit is brazed or welded together, it requires considerable extra equipment to perform a major repair (an internal repair). If the unit is bolted together, it still is a major overhaul to service anything within the unit, but there is not as much special equipment needed for special tearing down and assembly.

It is considered good practice to remove the complete hermetic unit from the cabinet and recondition it in the shop if any internal difficulties arise.

Servicing of hermetic refrigerators may be divided into two major divisions:

a. External repairs
b. Internal repairs

17-2. EXTERNAL SERVICING OF HERMETIC UNITS

External servicing means all those service operations which do not involve breaking into the refrigerant system except through service valves. Most of the external repairs can be done on the customer's premises.

Some of the more common external service operations are:

a. Cabinet hardware
b. Cleaning
c. Noise (rattles)
d. Electrical
   (1) Thermostat
   (2) Interior light and circuit
   (3) Power circuit
   (4) Fan motor
   (5) Relay
   (6) Capacitor
   (7) Motor terminals
   (8) Defroster
   (9) Defroster controls
e. Diagnosing of all the troubles in the unit
f. Charging, discharging, purging, and adding oil, if the unit is

equipped with service valves or service valve attachments.

17-3. CLEANING THE MECHANISM

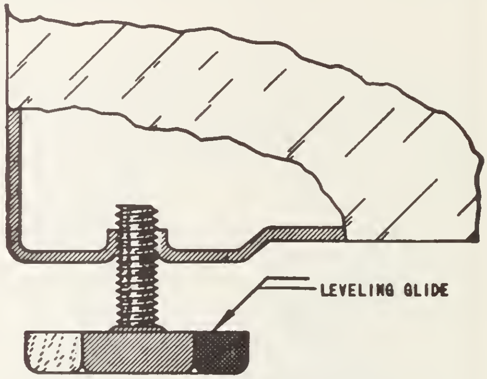
The hermetic refrigerating system is a heat transfer mechanism as much as the conventional system. Provisions must be made to allow air to circulate around and through the unit and condenser. Further, the condenser and dome must be kept as clean as possible, because dirt and lint will act as heat insulators. Periodic cleaning, approximately each three months, is very necessary for economical operation and long life. One outstanding advantage of the Monitor Top General Electric unit was that the owner kept the condenser clean, if for appearance only.

The best way to clean the hermetic mechanism is with a small vacuum cleaner or a special vacuum cleaner nozzle with a brush attachment. The vacuum cleaner eliminates raising a lint cloud to circulate in the room or to settle on the floor. It is also quicker and more thorough than hand brushes or cleaning cloths. If a brush or cleaning cloth is used, place a paper or cloth on the floor underneath the unit. If the unit uses a motor-driven fan, be sure to turn off the power (pull the plug) before proceeding with the cleaning. It will be found efficient and economical to partially remove the unit (especially remove the baffles and unbolt the condenser guard) to perform a good cleaning job.

17-4. EXTERNAL NOISE ELIMINATION

Most external noise in the refrigerator comes from rattles. Loose baffles or ducts, tubing touching anything while vibrating, an uneven floor which may cause a list (leaning to one side) of the condensing unit and finally fan and motor noises are all causes of noise.

A loose cooling unit door and loose articles on shelves that are not evenly placed on their supports may also cause annoying rattles. A rattling noise originating in the unit may indicate that the unit is laboring harder than in the past. To determine if there is an extra load on the running parts the electrical



17-1. A cabinet leveling screw. (Norge Sales Corp.)

load test is best; or one may sometimes determine if the unit is overloaded by its starting behavior (3 seconds to operate relay is the average time).

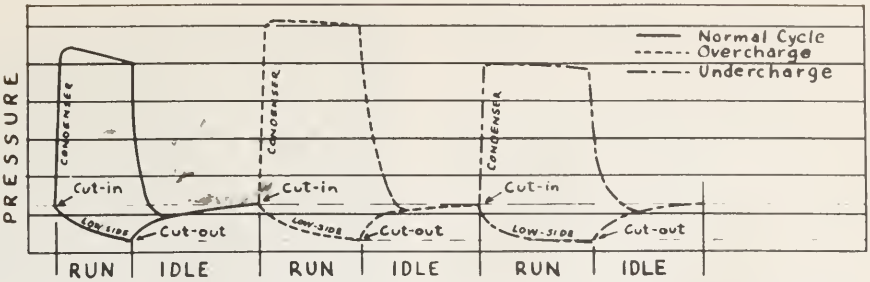
If the cabinet is on an uneven floor the cabinet can be leveled by adjusting the two screw type floor pads located at the front of the cabinet, Figure 17-1.

If the tubing is rattling against parts of the refrigerator, it can be carefully bent away from contact. If the tubing is taut and has a vibration or hum, this noise can be reduced by clamping rubber blocks on the tubing to stop the harmonic vibration.

Loose baffles and ducts can be easily secured by using self-tapping sheet metal screws.

17-5. SERVICING THE MECHANISM

Many manufacturers provide exchange service on the complete re-



17-2. Three capillary tube system cycles; normal, overcharged, and undercharged. (Allin Mfg. Co.)

frigeration machines exclusive of the external controls, fans and cabinet. In most cases it is advisable to use this service. In case a manufacturer has gone out of business or if it is impossible to obtain a replacement mechanism, the procedures recommended in the following paragraphs may be useful.

There are several types of hermetic refrigerating machines on the market. They vary in size from 1/20 H.P. to 7 H.P. Their construction varies between the sealed welded units with no external valves or moving parts, those that are welded, but have external fans, those that are welded are equipped with service valves or valve attachments, and finally, those that are bolted together and are completely serviceable without special tools. All of these can be repaired, but some require more equipment than others.

The general service procedure is to discard the refrigerant and the oil from the machine, dismantle the machine and make the necessary repairs (motor, compressor, refrigerant control), assemble the unit with temporary valves, test the unit (test for leaks), evacuate, dry the unit, charge it with oil and refrigerant, test the unit (recording thermometers, wattmeters, etc.), test for leaks, disconnect the temporary valves and finally give the unit a test run in a 100 F. room.

17-6. DIAGNOSING MECHANISM TROUBLES

Many methods can be used to find the trouble. A lack of refrigerant is usually indicated by the cooling coil being only partially frosted, but that part which is frosted is frosted very well.

Figure 17-2 shows typical pressure curves for a capillary tube system when it is overcharged, undercharged and also a normal cycle.

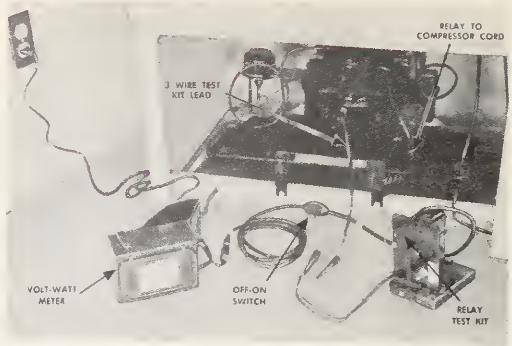
A leaky check valve will be indicated by the suction line warming rapidly starting at the compressor as oil and hot gas backs up into it as soon as the compressor stops. A restriction on the high side (high side float or, capillary tube, filter, dehydrator or screen) will be indicated by continuous running, no refrigeration and the liquid refrigerant will be found stored on the high side. This liquid can be detected by carefully using a small torch flame on the condenser and that part that contains liquid will stay relatively cool while the metal with no liquid back of it will warm rapidly.

A partial restriction will be shown by frost occurring at that point. This frosting quite frequently occurs at the filter screen, and dryer.

A compressor housing that is warmer than usual may indicate a unit running at a below normal voltage, a quantity of air in the system or a lack

of oil. The voltage can be easily checked with the use of a voltmeter. Air in the system can be checked by purging. A lack of oil will be indicated by a noisy unit. A lack of oil usually means that the oil has become lodged in the cooling coil.

In those units that have the condensing unit mounted above the cooling unit (Coldspot, Westinghouse, etc.), this condition can sometimes be remedied by putting very hot water in the ice cube trays. This extra heat boils the refrigerant violently and it may carry the oil back to the condensing unit. Some service men use a torch flame for this operation, but it is a dangerous practice. Drastic cases may require removing the unit and setting it upside down for a few minutes to start the oil back to the cooling unit. An oil-logged cooling unit is indicated by a lazy cooling coil, that is the cooling coil doesn't frost evenly.



17-3. Testing the electrical units of a hermetic system. Note the volt meter, wattmeter and substitute relay. (Norge Sales Corp.)

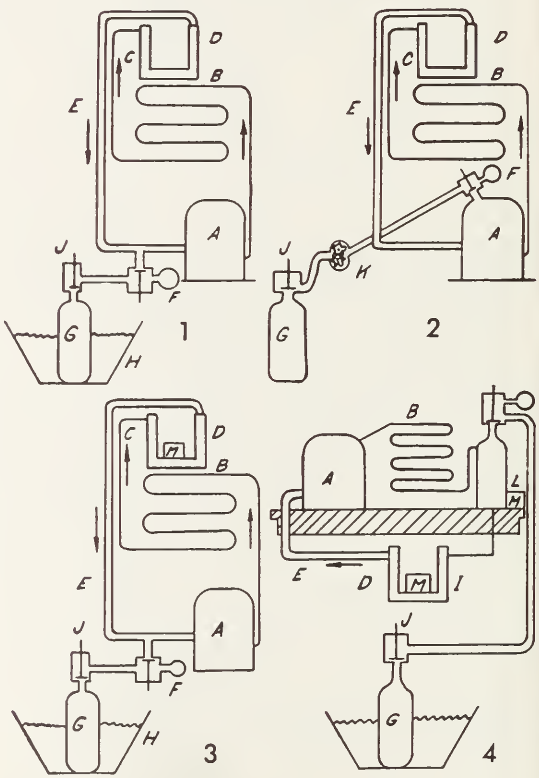
17-7. DIAGNOSING ELECTRICAL TROUBLES

Many hermetic systems are needlessly replaced because the service man concluded that the internal mechanism was faulty when the trouble really existed in the external electrical devices.

For example, if the mechanism will not start, or if the unit hums but will not start, or if the unit short cycles, the trouble could be in the external electrical circuit. The fault may be in the:

1. Power-in connections
2. Thermostat
3. Wire terminals
4. Relay
5. Capacitor (if the unit has one)

Each and all of these devices must be checked carefully before the unit itself is determined faulty. These parts can only be checked by removing them



17-4. Charging a hermetic unit. 1. Boiling the refrigerant in; 2. Pumping the refrigerant in; 3. Using dry ice in cooling coil; 4. Using dry ice on a HSF unit; A. Compressor; B. Condenser; C. Capillary tube; D. Cooling coil; E. Suction line; F. Valve attachment; G. Refrigerant cylinder; H. Hot water; J. Cylinder service valve; K. Pump; L. High side float; M. Dry ice.

from the wiring system and then

1. Checking them independently or
2. Temporarily substituting a test part or an exact replacement to see if the unit will run with the new part, Figure 17-4.

Such faults as open circuits, grounded electrical wires can be easily checked with a test light.

It is strongly recommended here that Chapter 6 be studied thoroughly before attempting to shoot trouble in the electrical units.

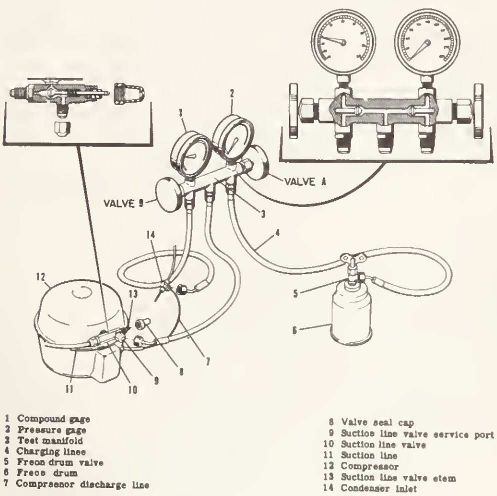
17-8. HERMETIC SYSTEM TROUBLE SHOOTING

TROUBLE	CAUSE	REMEDY
Unit does not run	1. Power Source (a) Fuse (b) Broken Wire	Use test light
	2. Cord or plug	Inspect
	3. Thermostat	Short out thermostat with a test lead
	4. Wiring	Use test light or replacement relay.
	5. Circuit Breaker	Short out circuit breaker.
	6. Motor-Compressor	Disconnect motor leads and install tester
Unit runs but does not refrigerate	1. No refrigerant	Install gauges low readings
	2. Poor Compressor	Install gauges - low side above normal
	3. Restriction in System	Install gauges Low side very low High side pressure low for temperature.
	4. Overcharge	Install gauges Both gauges show an above normal reading.
Unit runs but refrigerates poorly	1. Thermostat Setting	Check setting
	2. Inefficient Compressor	
	3. Moisture in system Intermittent freezing	Install dryer
	4. Low on refrigerant (Poor coil frosting)	Charge
	5. Partial Restrictions	Inspect for buckles or kinks in line.

Noise	1. Compressor	Replace
	2. Tubing rattles	Install vibration clamps (rubber clamps)
	3. Uneven floors	Level
	4. Loose parts	Tighten

17-9. CHARGING THE UNIT

If it is found that the hermetic unit needs refrigerant, the methods used to add refrigerant are as follows: First, one must remember that a pressure difference is needed to move the refrigerant from the refrigerant cylinder into the system. Figure 17-4. Either the compressor must create this pressure difference (1), another compressor or pump must create this pressure (2), or the unit must be cooled (water ice, or dry ice, or refrigerating unit) (3) and (4). In any method the refrigerant cylinder should be heated (never an open flame) with hot water.



17-5. A hermetic system benig evacuated and charged by using a gauge manifold. Note the disposable service cylinder.
(Franklin Mfg. Co.)

When charging a partially charged unit, a little refrigerant should be added and the unit should then be allowed to cycle. Proper charge is best indicated by the frost on the cooling coil and when the frost line starts to come down the suction line, purge out a little of the refrigerant.

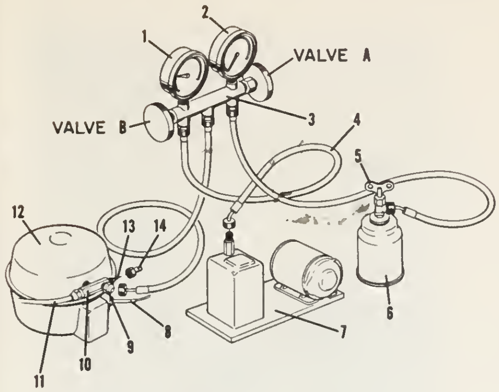
The service connection lines must be absolutely clean and free of air (moisture). This cleaning can be done by passing refrigerant through the lines before the charging refrigerant is allowed to pass through it. For example, in 1, have the valve loose at (F) and use the cylinder gas in (G) to blow out the lines. In some models (F) may be located on the cooling coil (D) or on the compressor dome (A). This process works if the service valve attachment is on the low side.

In part 2, a gear pump is shown but a vane pump or piston pump may also be used. It is important that the refrigerant be carefully weighed as it goes into the unit. This practice calls for the cylinder and the water pail (H) to be mounted or suspended from a weighing scale.

In part 3, dry ice or water ice (M), is put in the cooling coil (D) to help create a low pressure in the system. This is a slow process which requires boiling of the refrigerant in the refrigerant cylinder (G) and condensing it in the cooling coil (D).

Part 4 illustrates the charging of a hermetic system that has a top-mounted condensing unit and a high side float (L). Ice is put around the high side float and in the cooling coil. Remember that loss of refrigerant means a leak in the system. Locate and correct the leak before charging the system.

Many of the larger hermetic sys-



1 Compound gage
2 Pressure gage
3 Test manifold
4 Charging lines
5 Freon drum valve
6 Freon drum
7 Vacuum pump
8 Compressor discharge lines
9 Suction line valve service port
10 Suction line valve
11 Suction line
12 Freezer compressor
13 Suction line valve stem
14 Valve seal cap

17-6. Evacuating and charging a system using a gauge manifold, a vacuum pump and a disposable refrigerant cylinder.
(Franklin Mfg. Co.)

tems have service valves. To charge a system equipped with these service valves one may use one of two methods.

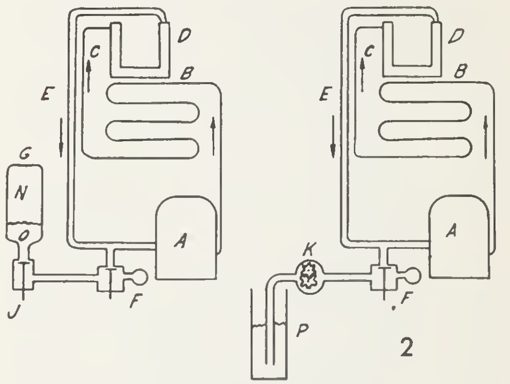
The system can be evacuated using its own compressor as a vacuum pump and then it can be charged. If the refrigerator has service valves a gauge manifold may be used and it may be charged as shown in Fig. 17-5.

Another method is to use a special vacuum pump to evacuate the unit and then charge it. Figure 17-6.

17-10. ADDING OIL TO THE SYSTEM

Only rarely is it necessary to add oil to a hermetic system. Occasionally a large refrigerant leak or a leak that has lasted a long time with a considerable refrigerant loss will make it necessary to add oil. The leaking refrigerant will always carry some oil with it and the oil (dissolved) must be replaced. The conventional method of adding oil to a system may be used if the hermetic unit is completely equipped with service valves. That is, the oil can be syphoned in or poured in.

However, some hermetics that have service valve attachment devices and provide no means to shut off the flow of refrigerant may need either one of the two systems shown in Figure 17-7. In (1), the correct amount of oil (O) is put in a service cylinder (G) and a small amount of refrigerant, the same as that in the system, is also put in the cylinder to create a pressure (N). The cylinder is inverted and connected by absolutely clean lines to the system, (J) to (F). Be sure the cylinder pressure is higher than the system pressure. Then open valves (J) and (F) and the oil will be forced into the system. In (2), a vane or gear pump (K) is used to syphon oil out of a clean and dry graduated container (P) and force it into service valve attachment (F). A hand pump may be used to perform the same function.

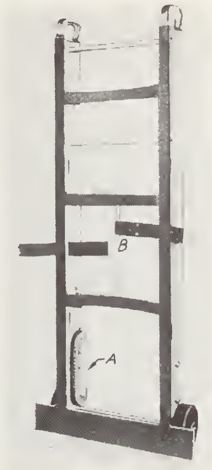


17-7. Adding oil to the hermetic unit. 1. Bomb method; 2. Pump method; A. Compressor; B. Condenser; C. Capillary tube; D. Cooling coil; E. Suction line; F. Valve attachment; G. Refrigerant cylinders; J. Cylinder valve; K. Pump; N. High pressure refrigerant gas; O. Oil; P. Oil container.

17-11. REMOVING THE SYSTEM

After a complete and patient check-

ing of the unit has determined that there is some serious mechanical or electrical trouble inside the unit, the unit should be removed from the cabinet and taken or sent to some thoroughly and specially equipped shop for repair.



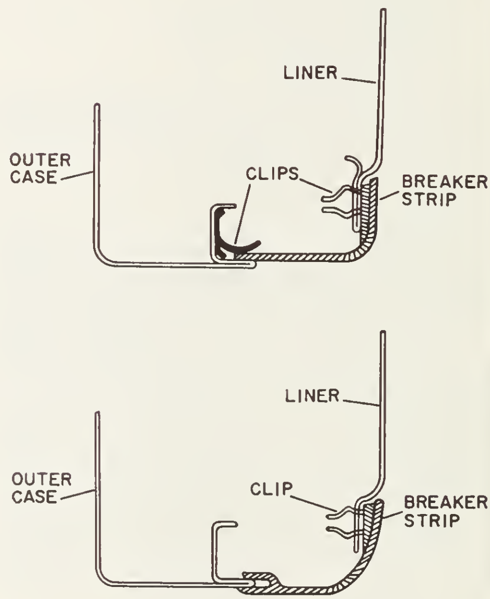
17-8. An appliance truck. A strap (B) that can be crank tightened; holds appliance in place. In addition to the wheels, a roller bearing tread (A) is mounted on each skid to help move the appliance over irregular shapes. The hand rails are also skids to aid moving the appliance in and out of trucks.
(Stevens Appliance Truck Co.)

The best policy is to use a replacement unit while the original is being repaired. If this cannot be done, supply the customer with a complete refrigerator loaner, while the cabinet and all of the unit being repaired are taken to the shop for service and overhaul.

It is of utmost importance to protect the refrigerating unit while it is being moved. It is very easy to make cradles or crates to hold these mechanisms. Wooden frames and C clamps provide an easy means to hold the parts from being injured while in transit.

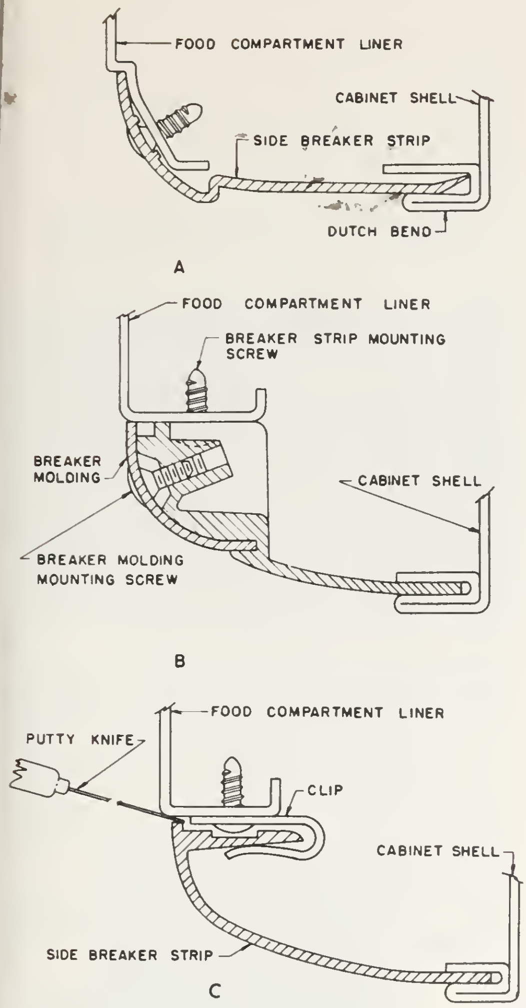
The complete cabinet, if moved, should be shrouded in a special padded blanket while being moved in a truck, then it is mounted in a hand cart to provide safe and easy moving around a building and up and down stairs.

17-9. Correct method of handling a refrigerator on stairs. Note how the roller tread assists over stair treads.
(Stevens Appliance Truck Co.)



17-10. Cabinet frame breaker strips. In one case the plastic breaker strip is held by clips and in the other drawing the breaker strip is grooved and slips over the edge of the metal.
(General Electric Co.)

A truck for moving refrigerators is shown in Figure 17-8. This truck has a strap that can be tightened with



17-11. Three methods of fastening breaker strips to the cabinet; A. Visible sheet metal screw; B. Breaker strip and moulding method; C. Clip method. (Philco Corp.)

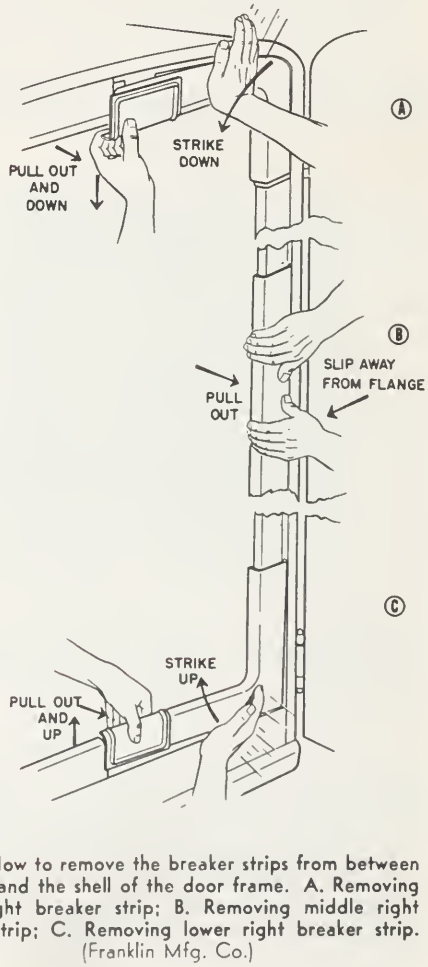
a crank. The rails are used as skids to slide the unit in and out trucks. See Figure 17-9.

The procedure for removing the unit from the cabinet varies because: (1) some of the cooling units are removed from the rear of the cabinet; (2) some of the cooling units are removed from the front of the cabinet (by way of the cabinet door).

The refrigerant lines are sometimes run just under the door frame breaker strips. These breaker strips must be removed in order to remove the lines.

These strips are usually made of a plastic material. Figure 17-10. Several other designs of cabinet frame breaker strips are shown in Figure 17-11. Note the several methods used to fasten the breaker strips to the cabinet shell and the liner.

The breaker strips must be removed very carefully or they will break. One method of removing these breaker strips is shown in Figure 17-12. Figure 17-13 illustrates two tools which are of considerable help when removing the strips.

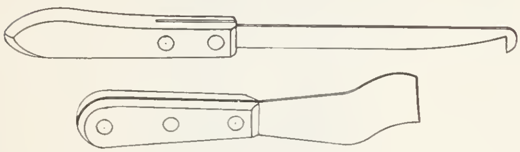


17-12. How to remove the breaker strips from between the liner and the shell of the door frame. A. Removing upper right breaker strip; B. Removing middle right breaker strip; C. Removing lower right breaker strip. (Franklin Mfg. Co.)

The cabinets which have the cooling unit removed from the rear of the cabinet are not difficult to dismantle.

Cabinets which require removing the unit from the front of the cabinet call for great skill and patience on the part of the service man. The hardest part is removing and installing the breaker strips. The mechanism is then removed as shown in Figure 17-14. One must be very careful not to link or buckle the refrigerant lines.

Some cabinets are of the double door design and the strips between the



17-13. Tools for removing plastic strips on cabinets and doors.
(Gibson Refrigerator Co.)

two compartments must be removed before the unit can be taken out. Figure 17-15 shows this strip being removed. Note the heater wire that prevents sweating of this million plate.

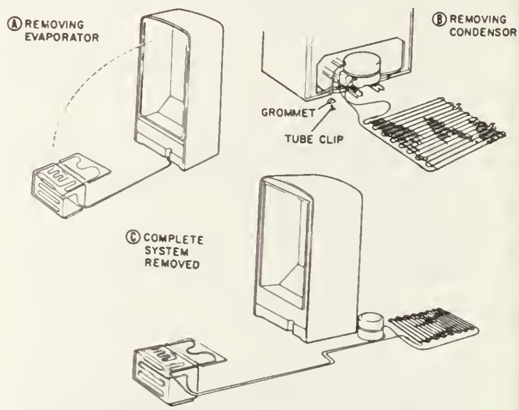
The compressor and condenser are usually fastened to the rear of the cabinet by four to six mounting screws and bolts. Do not abuse the mechanism while removing these devices, Figure 17-16.

17-12. DISMANTLING THE UNIT

The method of dismantling a hermetic system varies depending on its construction. The following general rules apply to all types of units.

a. CLEAN THE OUTSIDE OF THE UNIT THOROUGHLY. Mineral spirits, obtainable from most oil companies, is probably the best general cleaner. Carbon tetrachloride is excellent, but it must be used with caution. A special booth with a grate bottom, having drainage facilities, equipped with a pump and spray nozzle and ventilated, is a good thing to have in a shop doing volume work. Local fire and industrial hygiene regulations must be followed, so one should obtain permission to install a cleaning booth if it uses flammable or toxic fluids.

b. REMOVE THE REFRIGERANT. If the unit is equipped with service valve, or service valve attachment plugs, the refrigerant should be purged into the open through lines equipped with special oil traps. Do not purge methyl chloride or any other inflammable gas into a sewer because of the danger of explosions. In fact, none of the refrigerants should be released into a sewer, due to their harmful effects relative to excluding oxygen or due to their corrosiveness. They also carry oil vapors and these oils may cause fires or explosions in the sewer system. It is best to release the refrigerant to the atmosphere. That is, pipe the refrigerant to the roof of the building and baffle it so liquid can never spray on any one. It is very important to trap the oil by putting a tank in the line.



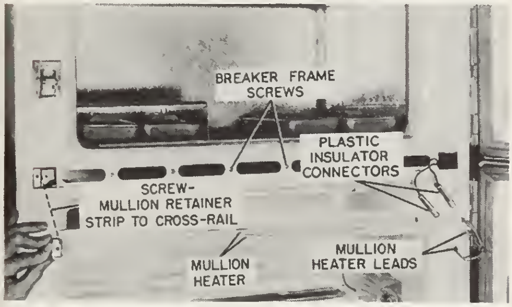
17-14. The correct procedure for removing a front-mounted refrigerating unit from a cabinet. A. Removing the cooling coil; B. Removing the condenser; C. Removing the compressor and lifting the cabinet off the refrigerant lines.
(Franklin Mfg. Co.)

If the system is not equipped with valves of any kind, the unit must be

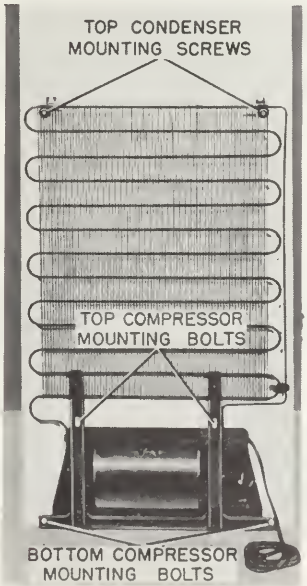
cut open. Several methods may be used. One method is to cool the unit (dry or water ice), put the unit in an exhaust ventilated booth and then cut liquid line at the outlet of the condenser. Another way is to use a piercing tool. This tool clamps on the line and is equipped with a line connection. This tool has a piercing tool that looks like a valve stem built into it. Simply clamp the tool on the line, connect the purge line to it, and tighten the piercing screw and then release. Figure 17-17. The small hole pierced in the line will release all of the refrigerant. One must be especially cautious of some of the older hermetics which used sulphur dioxide as a refrigerant.

Such valves then remain on the line as permanent fixtures. The seal between the valve body and line is made gas tight by means of a synthetic rubber gasket.

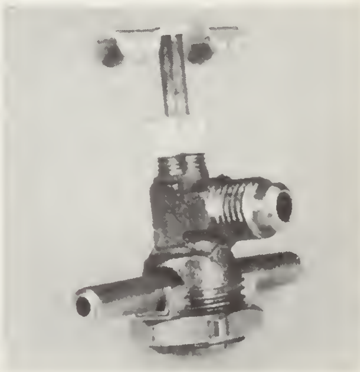
c. REMOVING THE OIL. It is not always necessary to remove the oil. In fact, it is almost impossible to remove all the oil until the unit is opened. However, it may be convenient to remove the oil especially if the compressor dome must be mounted in a lathe to be cut open or turned as the old weld is ground off on a power grinder. If the system uses sulphur dioxide it should be evacuated to remove the sulphur dioxide dissolved in the oil. This is one method of removing the unpleasant odor. If the sealed unit is of the bolted construction type, the oil is usually left in the unit until



17-15. Removing the mullion plate in a two-door cabinet. Note the heater wires that warm the mullion to keep it from sweating.
(Hotpoint Co.)



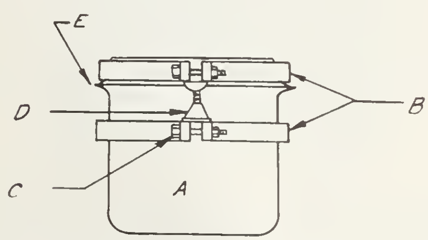
17-16. The mounting bolts and screws that must be removed when replacing the refrigerating mechanism.
(Hotpoint Co.)



17-17. An accessory service valve which may be installed on a hermetic refrigerator by clamping it on a refrigeration line. A synthetic rubber gasket provides a gas tight connection between the valve body and the line.
(Mechanical Refrigeration Enterprises)

it is dismantled. The old oil may be drained off, carefully measured to assure exact replacement and then stored in a drum and sold to oil reclaiming companies. This old oil should never be used again, unless it is completely redistilled and thoroughly dehydrated. If it is positively known that the oil is clean and dry, it may be stored for future use in a clean and dry container IMMEDIATELY after it is removed from the unit.

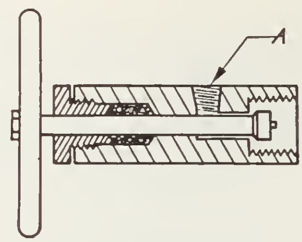
d. DISCONNECTING THE LINES. The lines (liquid and suction) are usually soft soldered or silver brazed to the cooling unit and condensing unit. It is not usually necessary to disconnect the suction line from the cooling coil. Occasionally, when the liquid line is a capillary tube, it is advisable to disconnect it on both ends. All the openings should be immediately sealed if it is intended to use lines and parts over again. This sealing can be done either by pinching the lines or using expanding corks (synthetic rubber or natural corks). The openings into the condensing unit should also be plugged to keep the unit as clean as possible. Masking tape is sometimes used to temporarily seal the openings.



17-18. One method of pulling a compressor dome apart. A. Dome; B. Steel straps; C. Clamp bolts; D. Screw jack; E. Welded joint.

e. OPENING UNITS. The welded units are easily opened by either grinding away the welded seam or removing the weld bead by mounting the unit in a lathe and cutting the weld bead away with a cutting tool. This latter method requires a large swing lathe with special mounting brackets on a faceplate. Some of the domes can be mounted in a chuck. Some service departments use a vertical mill with a rotary cutting tool to cut the weld. See paragraph 12-34, page 315, and Figure 12-24.

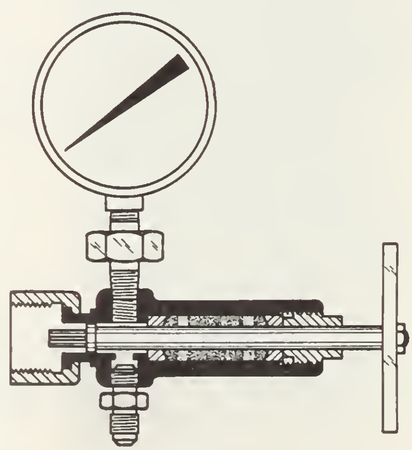
Remove a minimum of material as sufficient base metal must be left for



17-19. A service valve attachment used on semi-hermetic or hermetic units. A. Opening for a gauge.

the assembly to be arc welded together again.

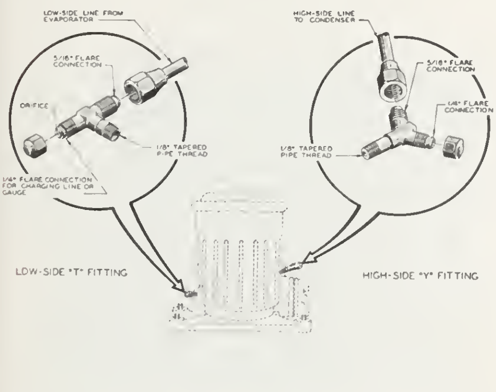
After the compressor dome weld is removed, the dome can usually be lifted off the base and the motor and compressor exposed. Some of the models have the dome pressed on the base in addition to the weld. The dome must, therefore, be pulled off the base. To remove a press fit dome, clamps are generally used to hold the dome and a



17-20. A service valve attachment and the valve port to which it attaches.
(Norge Sales Corp.)

17-21. A valve kit and adapters for use on various makes of semi-hermetic and hermetic refrigeration units. (Mueller Brass Co.)

special arbor press, or screw jacks are used to force the two apart, Figure 17-18. These clamps are made of heavy strap iron bent to fit the dome and clamped on tightly by means of bolts. Most domes have mounting lugs that can be used with the clamps. It may occasionally be necessary to weld lugs on the dome to secure a purchase point to pull them apart. Hydraulic pressure is also sometimes used to remove the dome. Clean the inside of the dome thoroughly before proceeding further.



17-22. The use of "T" and "Y" fittings to attach gauges to hermetic system. Small orifices prevent any appreciable refrigerant loss. (Gibson Refrigerator Co.)

17-13. SERVICE VALVES AND ADAPTERS

Most hermetic refrigerators do not have service valves. Some have fittings to which valves may be attached for service operations, then removed when the service work has been completed. Others have no service valves, neither do they have any provision for fitting them with valves. However, in order to service any type of refrigerator some service valves must be used. It then becomes a matter of fitting the necessary valves to the mechanism. Commercially there are valve attachments which can be fitted to any mechanism. Figure 17-19 and 17-20 illustrate service valve attachments which may be installed on refrigerators which have fittings for service valves. It should be noted that for these refrigerators the adaptor provides a means of operating the valve in the mechanism, also it provides an opening for a service gauge or a refrigerant cylinder or both. Figure 17-21 shows an assortment of valve adaptors which will enable the service man to make proper valve connections on any refrigerators which have fittings for valve adaptors.

A way to attach gauges to a hermetic system is shown in Figure 17-22. The T and XY fittings are connected to the compressor body with pipe threads. A flare connection is used to attach the refrigerant lines. The third opening is capped with a $\frac{1}{4}$ in. flare cap. The opening in the fitting at this connection is very small. If the machine is adjusted to produce close to atmospheric pressures, and these caps are removed, the gauge or manifold lines may be attached without losing any appreciable

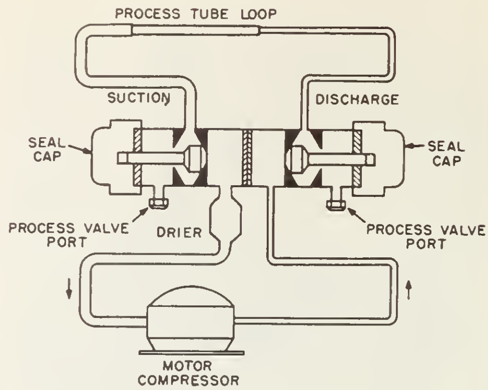
amount of refrigerant. The unit should be idle for several minutes before installing the lines or removing them. Furthermore, the connecting lines should be purged before tightening the connectors.

17-14. REPAIRING HERMETICS IN THE FIELD

One company has a new technique for servicing hermetics in the field. Their method enables a trained serviceman to replace the motor-compressor unit, or any other part of the mechanism without removing the refrigerator from the premises. For example, if the motor-compressor needs replacing, a special unit is obtained

17-23. A replacement motor-compressor equipped with a manifold valve system.
(Philco Corp.)

that can easily be substituted for the malfunctioning motor-compressor. A replacement unit is shown in Fig. 17-23. A diagrammatic view of its assembly is shown in Fig. 17-24. The unit comes equipped with the special valve shown. It is very similar to the



17-24. A schematic diagram of a replacement motor-compressor equipped with a valve manifold.
(Philco Corp.)

gauge manifold valve system used for servicing (Chapter 11). Note that the discharge and suction opening lines are soldered together. The valves are two-way valves. Turned all the way in, the valve closes the opening to the compressor. Turned all the way out the valve closes the opening to process valve port (gauge openings).

The poor unit is removed by cutting the condenser and suction lines in such a place along the tubing that these lines can be re-soldered to the replacement tubing. The lines are first pinched, then wrapped in cloth and

17-25. Pinching the suction line prior to wrapping it in cloth and breaking it.
(Philco Corp.)

finally bent sharply at the pinch to sever them. Sawing is not recommended as chips may cause internal damage, Figure 17-25. The cut lines with the old unit now separated from the system is shown in Figure 17-26 with the lines sealed by pinching them firmly. After the new motor-compressor has been installed and the joints carefully soldered, the system must be carefully checked for leaks. It must be cleaned of air and moisture, and it must be charged. Figure 17-27 illustrates the connections necessary to perform these operations. The Freon-12 cylinder must contain clean refrigerant. The drier must have fresh, clean

17-26. The old motor-compressor removed and its refrigerant lines sealed by pinching. This protects the internal structure of the unit for shipment. (Philco Corp.)

desiccant and the connections must be tight. The manifold valves remain turned all the way in. To check for leaks valve V_2 is kept closed. A pressure of 50 psig is built up in the lines and cooling coil.

To purge the unit, valve V_2 is opened and then the Freon-12 cylinder valve is opened. One should purge several times to insure complete cleanliness and dryness.

To remove the service lines, close both V_2 and V_1 and then turn the manifold valves all the way out. All the lines can now be removed and the gauge opening ports can be capped.

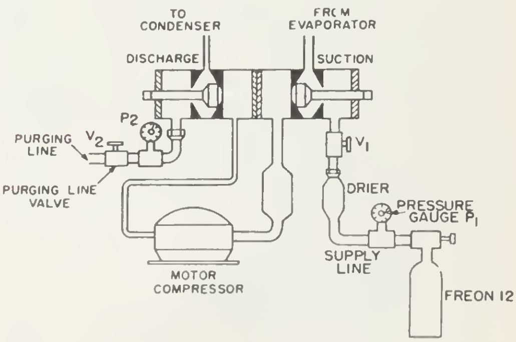
To charge the system connect as shown in Figure 17-28. Note that the cylinder is connected to the suction side. With the manifold valve in its position, the compressor is removing refrigerant from both the cooling coil and the refrigerant cylinder.

17-15. REPAIRING THE MOTOR

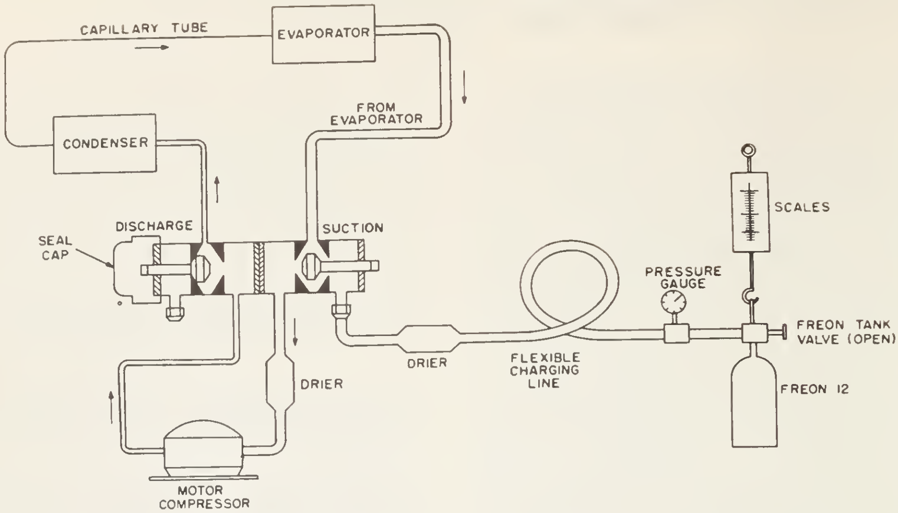
The most common trouble with hermetic mechanisms is a burned (overheated) motor. When the windings overheat, the insulation is destroyed and the stator coils short and ground. If the motor starting winding or running winding is faulty, the stator must be dismantled and rewired (rewound) or replaced. Specialists should do the rewinding. The wire must be exactly similar to the original, the same size and the same insulation.

Replacement or exchange stators are obtainable for most hermetic motors.

A burned out motor always means that the system has considerable foreign matter throughout. The system must be completely dismantled and thoroughly cleaned.



17-27. The connections needed to test for leaks and to purge the system. (Philco Corp.)



17-28. The connections necessary to charge the hermetic system equipped with a valve manifold. (Philco Corp.)

17-16. REPAIRING THE COMPRESSOR

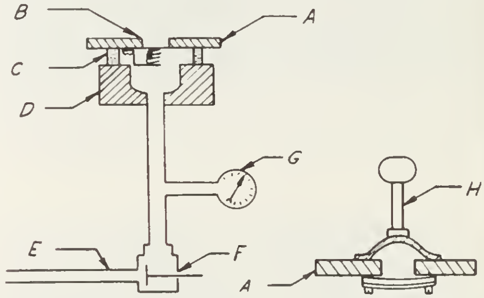
The repair of the compressor is naturally dependent on its condition. If the parts are badly scored and worn, the unit will usually have to be replaced. There are several hermetic replacement units on the market and these can be easily installed in place of the worn out condensing unit (Copeland, Servel, Tecumseh, Universal, Seeger, Lehigh, etc.).

If the trouble is in the compressor valves, the check valve or if it is dirt in the system all these can be repaired. It may sometimes be found necessary to manufacture a part. Most tool and die shops can make most of the parts to the extreme accuracies necessary. One must remember that the precision craftsmanship in these mechanisms hold to tolerances of plus or minus .0001 inch.

17-17. REPAIRING A RECIPROCATING COMPRESSOR

The most common compressor trouble is in valves and valve seats. The repair of these parts is exactly the same as for conventional compressors. The valve reed is replaced and the valve seat is reground on a surface grinder or in a drill press and then accurately lápped. Replacement valve reeds are available for most hermetic compressors.

It is imperative to test these valves before assembling the unit. This testing can be done by using fixtures and

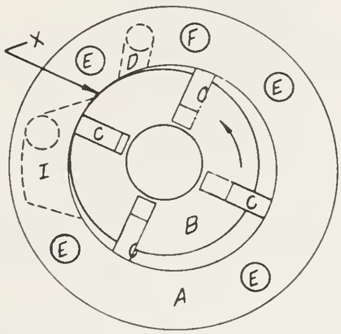


17-29. Testing compressor valves. A. Valve plate; B. Refrigerant oil; C. Synthetic rubber gasket; D. Fixture; E. Clean, dry, compressed air; F. Air valve; G. Pressure gauge; H. Vacuum cup.

synthetic gaskets or with a synthetic rubber vacuum cup, Figure 17-29. Noisy valves may be caused by excessive valve lift (or excessive pressure differences). The valve movement is usually measured in thousandths of an inch. The valve lift must be accurately

adjusted. Check the amount of lift before dismantling the valve (dial indicator). Too little valve lift will result in an inefficiently running compressor, and overheating.

A check valve can be checked much the same way. Because it is very important to keep these units as quiet as possible, the bearing and bushing clearances must be as small as possible (main bearings, connecting rod bearings, piston pin bushings and piston clearances).



17-30. Diagram of parts and adjustments on a hermetic rotary compressor. A. Housing; B. Rotor; C. Blades; D. Exhaust port; E. Bolts; F. Dowel pin; I. Intake port; X. Contact point between rotor and housing.

It is sometimes necessary to use an accurate engine lathe, and external grinder to achieve good results. Accurate micrometers are also of the utmost importance in order that the clearances and tolerances necessary for good performance may be obtained.

The main bodies or parts of the compressor are usually made of cast iron, the valves of spring steel, and the piston pins of high carbon steel (some repair shops use drill rod as replacement piston pins). If the replaced part is a moving part, it should be exactly the same weight as the old part, to keep dynamic vibrations to a minimum.

End play must be kept small to eliminate end play slap.

The oil pump must be in excellent condition and its pumping action checked.

17-18. REPAIRING A HERMETIC ROTARY COMPRESSOR

The instructions in Paragraph 17-15 also are true in the main for rotary compressors. In addition the rotating vane type of rotary compressor has two additional repair features:

a. The positioning of the roller housing to accurately locate the contact spot between the concentric roller and the eccentric housing is very important. In Figure 17-30 the contact point X must be very carefully adjusted. In this drawing four cap screws hold the housing (A) and an end plate up against the main housing. Point F is a dowel pin. The assembly is snugly assembled and the housing is lightly tapped until the rotor B binds when the shaft is turned by hand or by the electric motor. Then the housing is relieved a very , very little by tapping opposite to X until the binding is released.

b. The vanes C must be accurately fitted to the roller (B) and the housing (A). These vanes (C) must match very accurately in length to the roller (B) length and the housing length (A). The vanes must also fit the slots in the roller accurately. They cannot be too long or they will bind as they pass point (X). If they are too short they will permit blow-by as they pass point (X). The length of the vanes must exactly match the length of the roller and the length of the housing to prevent gas leakage past the ends of the blades.

The single or stationary vane type compressor has much the same fit problem as the rotating vane type. The parts must be accurately fitted together. The main bearing or main bearings must be in excellent condition. The length of the roller, the

housing and the vane must be extremely accurately matched. There must be no evidence of scoring.

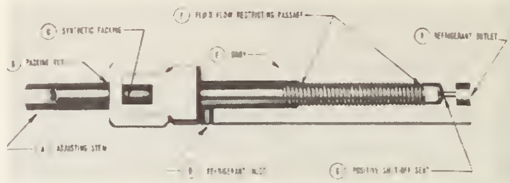
The vane is usually spring loaded to keep it riding on the roller. If this spring is too weak, it will allow the gas to by-pass the vane and will cause a loud clicking noise. If it is too strong it will cause an unnecessary load on the roller and cause rapid wear. Dowel pins are used to align the housing with the shaft.

17-31. A high pressure side float refrigerant control. A. Inlet; B. Outlet; C. Purging and service valve attachment fitting.
(Aminco Refrigeration Products)

Both of these compressors need sufficient oil at all times to keep the parts in a constant oil bath. It is necessary to clean all the oil passages and to clean or replace the oil metering screws.

17-19. SERVICING CHECK VALVES

All rotary compressors are equipped with check valves in the suction line or in the suction passages. This check valve prevents the oil in the compressor from backing into the suction line and up into the cooling coil, during the off cycle. As mentioned



17-32. An adjustable capillary valve.
(Standard Refrigeration Co.)

previously, the indication of a leaky check valve is the rapid warming of the suction line as soon as the compressor stops due to the warm oil backing into the suction line. Another indication is the defrosting of the cooling coil starting at the suction line connection of the cooling coil.

Whenever possible replace the defective check valve. Always test the check valve for leaks by using the air pressure or vacuum test in a manner similar to the way a compressor valve is tested.

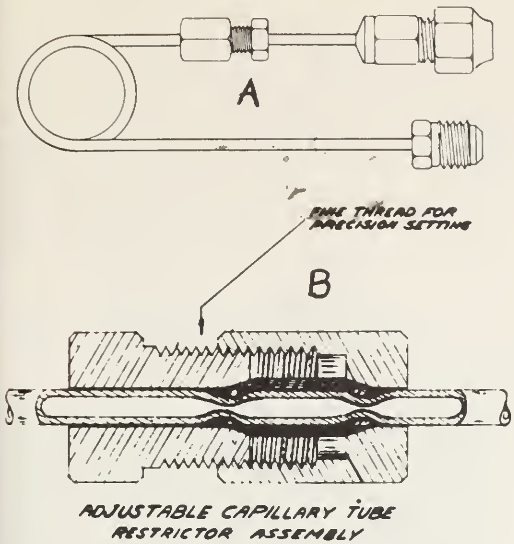
See Chapter 5 for more information on check valves.

17-20. SERVICING HIGH SIDE FLOATS

The operation of the high side float is described in Chapter 5. A defective high side float should be replaced. Whether the float is collapsed, leaking, or whether the needle and seat are stuck open or shut or leaking, the best practice is to put in a new float assembly. A typical universal replacement high side float unit is illustrated in Fig. 17-31.

17-21. SERVICING CAPILLARY TUBES

Broken or clogged capillary tubes are the most common troubles encountered. These capillary tubes are



17-33. The internal design of the adjustment used on the capillary tube. A. Shows the complete assembly; B. Shows how the adjustment operates. (Allen Mfg. Co.)

replaced by installing either a new correctly sized capillary tube or an adjustable capillary tube. Fig. 17-32. This control has a strainer mounted in the inlet fitting. Another type of adjustable capillary tube is shown in Fig. 17-33.

To check a capillary tube for restrictions compare its pressure drop with the pressure drop of a new tube of like specifications, using the same refrigerant and the same inlet pressure.

17-22. DRYERS AND FILTERS

It is important to keep the inside of a refrigeration mechanism as chemically clean as possible. When the system is overhauled the parts should be dehydrated and evacuated after assembly, but there are many crevices and corners that are almost impossible to clean out. Furthermore, whenever gauges are put on a system, it is difficult to prevent foreign matter from entering the system.

The only positive method of keeping the system clean and dry inside is to install dryers and filters in the refrigerant circuit. A solid moisture absorbent will usually do a very satisfactory job. Silica gel is an excellent moisture absorber. This silica gel must be of the very best quality as it must not decompose to dust and start circulating with the refrigerant. One company has produced a bead silica gel that gives excellent results.

One can easily determine if a dryer is absorbing water as it will become warm as it absorbs moisture.

It is very important that one never use a liquid drying agent in a unit equipped with solid desiccant. The liquid dryer chemical will go into the solid desiccant and release the moisture already trapped in the dryer. For the same reason, a solid desiccant should not be put in a system that already has a liquid dryer. To avoid this practice, the systems should be labeled when a liquid drying agent has been added.

Activated alumina may be used with good results as a desiccant. It also has the advantage of reacting with any acids formed in the system. Calcium chloride is an excellent dryer but it can not be left in the system as it will decompose and start circulating. It is an excellent temporary dryer if it is removed in a short time (24 hours, approximately). The moisture absorbent properties of these desiccants are shown in Figure 17-34.

Anhydrous calcium sulphate has also been successfully used as desiccant. It can be left in the system permanently.

The Refrigeration Electrical Manufacturers Association has recommended that dehydrators be rated as to cubic inches of desiccant. Figure 17-35 shows the cubic content corresponding to the horse power for which each size dryer is recommended.

Desiccant	Mesh	Refrigerants	Absorption From Liquid, % of its Own Weight
Silica gel	8-20	S,M or F	16
Calcium Sulphate	4-6	M or F	6.6
Activated Alumina	8-10	S,M or F	12
Calcium Chloride*	12		100
Calcium Oxide*		M or F	

*Temporary installation only

17-34. Dryers (desiccants) and their physical properties. S is sulphur dioxide; M is methyl chloride and F is for the Freon refrigerants.

Dryers which are installed temporarily should be of the refillable type (preferably bolted), while the permanently installed dryers should be of the non-refillable type. All dryers are sealed by the manufacturer. Do not open them until immediately before their installation.

Dryers absorb water faster at lower temperatures. If at all possible, the dryer should be installed inside the refrigerator just ahead of the refrigerant control.

Strainers are of several types. The screen type is most popular. It is usually made of bronze, brass or monel wire and should be 100 to 120 mesh. That is, there should be 100 openings along a one inch rule length, therefore 10,000 holes per square inch. The popular screens are 100 × 90, 100 × 100, 120 × 108 and 120 × 120. The wire is usually .004 to .005 diameter. This size wire means the openings are about .005 square. Felts may be used. These felts are about 1/8 inch thick and should be made of special felt material. Wool batt is used to filter in some dryers. One company has a specially processed coarse cotton yarn wound in a diamond pattern over a metal frame. One of the latest filters makes use of powdered metal castings.

17-23. ASSEMBLING THE SYSTEM

Insuring cleanliness of all the internal parts of the mechanism is one of the most important steps in the assembly process. The inside of the compressor and the motor windings are usually the hardest parts to clean. A mineral spirits spray using an air pressure gun is probably the best way to clean these parts. Immersing the parts in a mineral spirits bath is also very effective. Carbon tetrachloride is an excellent cleaner but its fumes are dangerous. The parts must be oil dipped immediately after being cleaned with carbon tetrachloride or the iron and steel parts will start rusting.

DRYER SIZES

Cu. In.	Capacity, H. P.
2	1/8
3	1/6 to 1/4
6	1/4 to 1/2
9	1/2 to 3/4
12	3/4 to 1
18	1 to 1 1/2
30	1 1/2 to 3 H.P.
50	5 to 7 1/2 H.P.

17-35. Recommended dryer capacities in cubic inches based on the horsepower of the condensing unit.

It is absolutely essential to run the compressor after it has been assembled before welding the dome. It can be run for a few moments and its pumping ability and its noise level checked without danger of scoring the parts due to lack of oil. A vacuum gauge equipped

with a synthetic rubber tip can be held against the inlet opening of the unit while checking its pumping ability. A similarly equipped high pressure gauge may also be used on certain models. Running the motor provides a check of the electrical work for opens, shorts, grounds and suitable power.

17-24. WELDING COMPRESSOR DOME

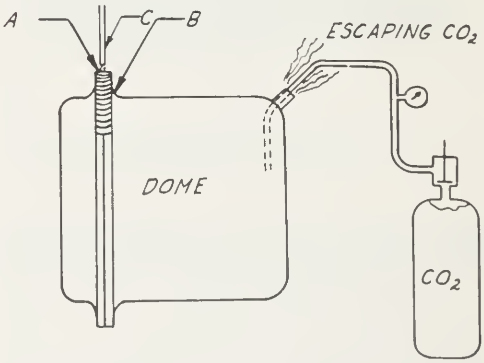
After the compressor has been checked, the dome can be welded in place. The best method of sealing the dome is arc welding. The speed with which arc welding may be accomplished allows only a very minimum of heat to go to the interior of the dome (compressor and winding). Brazing, gas welding, and silver brazing with a gas flame are slower and may in some cases overheat the wiring and ruin the insulation. A good safety practice is to bleed the dome with CO gas or nitrogen gas while the welding is being done to prevent an explosive mixture of oil fumes and air from collecting, Fig. 17-36. It is also important to cool the weld as quickly as possible after the weld is completed. Avoid the use of water. Use a damp cloth, a large block of copper, stream of cool air, or other means. Use reverse polarity coated electrodes during arc welding to minimize the heat that is released into the dome metal. It is very important to clean the metal surfaces for at least one half inch on each side of the weld to prevent dirt inclusions as these may cause blow holes which will leak. The welding should be done by a very experienced welder. The welding station must be well ventilated or the operator will develop respiratory illnesses. The arc must be shielded from eyes of passers-by. Do all the welding with the weld in the downhand position; i.e., turn the dome as the welding progresses. After the welding is completed, the motor should be tested again for running characteristics.

Some repairmen weld domes as they are slowing turning in the lathe. Tack weld the dome in at least three equally spaced places before proceeding with the welding.

17-25. CONNECTING TUBING

After the motor-compressor dome has been assembled and welded, the suction tubing and the condenser tubing must be fastened to the dome.

These joints are best fastened by silver brazing. Silver brazing methods are described in Chapter 2. It is very important to remember that the joint must be clean, the parts must be securely mounted to prevent movement during brazing, and both parts to be joined must be brought up to the correct temperature at the same time (the compressor end of the joint usually requires more heat). Good silver brazing can only be achieved by practicing the correct method.



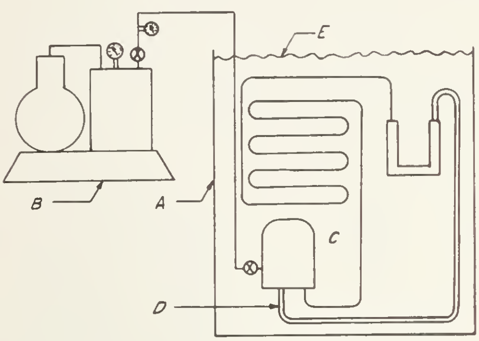
17-36. Welding a hermetic dome. A. Arc welded seam; B. Dome flange. Always clean all the surfaces before welding. Note the CO_2 being used as a flushing gas to prevent the collecting of explosive mixtures.

17-26. CHECKING LEAKS

After the unit has been assembled

it should be checked very carefully for leaks. There are several ways to do this testing. Carbon dioxide or nitrogen may be used; it is charged into the unit through the attachment or auxiliary valves. Build up a 20 to 30 psig pressure and test for leaks by immersing the unit in a water tank or by using soap suds. Then increase the pressure to 75 or 100 psig and check. Finally raise the pressure to 200 to 250 psig and check carefully for leaks again. Figure 17-37.

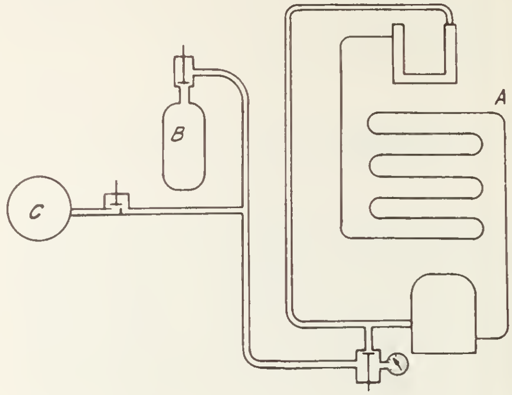
There is an element of danger in this operation in that the high pressures may cause serious injury to the tester if the unit should suddenly fail. It is therefore important to build up the pressure while standing in a safe place and also to use a high side wall on the tank to deflect any sudden eruption. Following the test it is necessary to thoroughly evacuate the system since all gas used in the test must be removed from the system.



17-37. Testing a rebuilt hermetic system for leaks. A. Water tank; B. Air compressor or inert gas source; C. Submerged refrigerating unit; D. Refrigerating lines; E. Water level.

Most companies prefer to use a refrigerant to test for leaks. A process similar to the one stated before is used, but a sensitive leak detector is used instead of soap suds or water. Note that the unit is checked for leaks before it is evacuated as any leaks would allow air and moisture to enter the system during evacuation or pump-down, Figure 17-38.

If a leak is detected and repaired it is of vital importance to check the complete unit for leaks again.



17-38. Preparing a system for testing for leaks with a leak detector. A. Refrigerating system; B. F-12 cylinder; C. Vacuum pump.

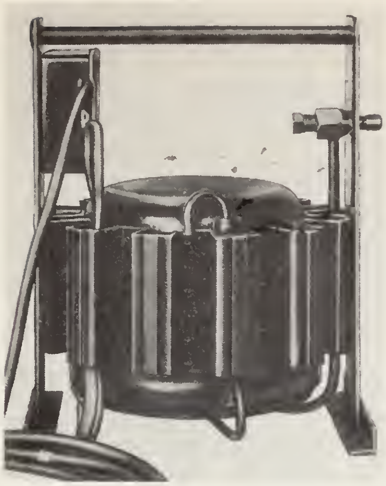
17-27. EVACUATING AND DRYING THE UNIT

The evacuating and drying of the unit is probably the most important part of all the assembly work. As closely as possible, the system should be absolutely 100% clear of air, moisture and other foreign matter. The steps to accomplish the result are as follows:

1. Evacuate the unit.
2. Charge with CO_2 to 50 to 100 pounds per square inch.
3. Evacuate the unit.
4. Charge with refrigerant gas (no liquid).
5. Evacuate the unit (warm the unit).

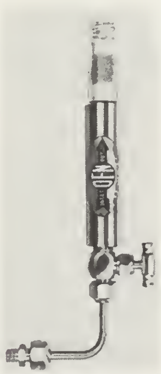
It must be remembered that the most careful evacuating and purging will not clean a unit that was carelessly put together allowing dirt to be left in the system.

A very good vacuum pump should be used to remove as much air as possible from the unit. A rotary pump,



17-39. A portable vacuum pump is used to remove air or refrigerant from a system. This is a rotary compressor directly driven by a motor. Note the line connection and the combination handle and stand.
(Frigidaire Div., General Motors Corp.)

due to its minimum clearance chamber on the evacuating side will produce the lowest or best vacuum in most cases, Figure 17-39. However, the best of pumps will not remove all the air. A pump that will produce a 28 inch vacuum is only removing 28/30 of the air or 93%. Furthermore, with a 28 inch vacuum any moisture particles



17-40. An indicator used to show the presence of moisture in a system. The lower left fitting connects to the service gauge opening. If the system refrigerant contains moisture and if some is purged through the green desiccant in the plastic cylinder, the chemical will turn purple.
(The McIntire Co.)

must be heated to 100 F. before they will evaporate and thus be pumped out as water vapor.

To remove the moisture one must heat the unit to some temperature that will not only vaporize it but will drive the moisture out of those little cracks and crevices that exist in numerous quantities in all units. For the same reason, the unit should be run for part or all of this operation to insure that all pockets in the compressor and in the bearings are agitated to release pocketed air plus warming the motor windings which are probably the greatest source of trapped moisture. It is considered good practice to evacuate for 8 hours at 250 F. or for 24 hours at 150 F. A drying oven, temperature controlled, is of utmost importance, Chapter 12. Carbon dioxide has an affinity or attraction for moisture and circulating it in the system helps to reduce this problem.

To eliminate more of the air, charge some refrigerant into the system. Next,

17-41. A monel screen pencil strainer that may be silver brazed into hermetic system lines.
(The McIntire Co.)

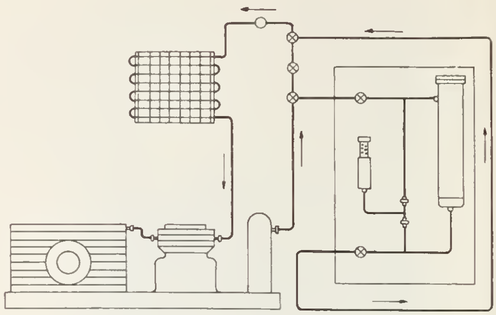
evacuate the system again. This will take out more of the air and only about .8% of the original air will now remain in the system. The remaining air may best be removed by purging the condenser after the system has been in operation for a short time.

There is a device on the market which will indicate moisture in the system. It is a silica gel cartridge using a litmus solution and if the refrigerant or air is passed through it, any moisture will cause the silica gel to discolor. See Figure 17-40.

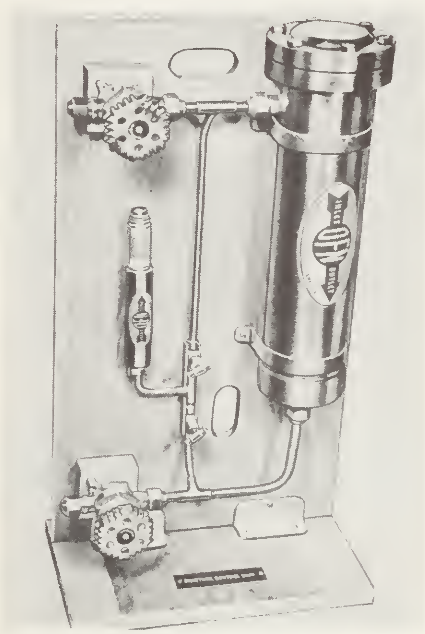
A small efficient pencil type strainer designed for hermetic systems is shown in Fig. 17-41. This unit may be silver brazed into the refrigerant circuit without injury to the strainer.

Figure 17-42 illustrates a dehydrating and indicating system which may be used in the drying of any refrigerating system.

Figure 17-43 illustrates diagrammatically how the dehydrating and indicating system should be connected to the refrigerating circuit.



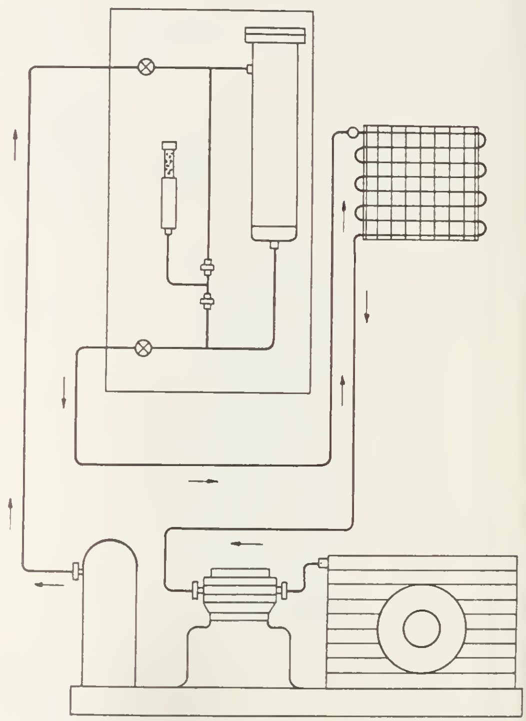
17-43. A complete dehydrating apparatus connected into the liquid line of a refrigerating system by a by-pass arrangement.
(The McIntire Co.)



17-42. A specially designed apparatus used to dehydrate any refrigerating system. It incorporates a moisture indicator which accurately indicates the moisture content in the system.
(The McIntire Co.)

By means of this system, the refrigerant can be circulated through the oversize dryer by positioning the valves shown. Then after the system has been operated for several hours, the test unit can be fed some of the refrigerant. If there is still moisture in the refrigerant, the green colored crystals in the test tube will change to a purple color. This operation is continued until the test tube crystals do not change color when refrigerant is admitted.

The dehydrator and the test tube can now be removed without disturbing the system, by simply closing the two de-



17-44. A dehydrator and moisture indicator permanently conected into the liquid line of a refrigerating unit.
(The McIntire Co.)

hydrator line valves and opening the middle valve.

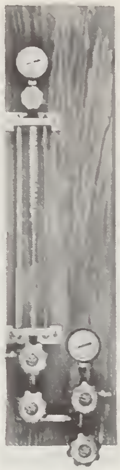
Figure 17-44 illustrates a dehydrator and indicating system which is connected permanently into the liquid line of a commercial unit. Such a unit makes it possible to continually dry the refrigerant and to test it for moisture at any time.

17-28. CHARGING THE UNIT

It is usual practice to charge the unit with oil before adding the refrigerant. The correct amount of oil is very important. A lack of oil will shorten the life of the mechanism, increase friction and cause noise. An overcharge of oil will cause the compressor to pump excessive amounts of oil reducing its refrigerant pumping capacity and also subject the compressor valves to severe strain. It will frequently require some study to determine the amount of oil charge. One of the best methods is to measure the oil removed from the unit at the time the unit is dismantled, also notice the oil level mark inside the unit and estimate the oil volume. Generally speaking, a rotary compressor uses between 20 and 30 ounces of oil. However, these figures are very general and the repairman is cautioned to use good judgment.

Since oil must stay in the system for years, it is vitally important to use the best lubricant obtainable. All of the reputable oil companies produce quite satisfactory refrigerant oils. Remember to clean all the charging lines. Refrigerant oils are available in several viscosities (ease of flow at different temperatures). Be sure to use the manufacturer's recommendations of viscosity for the refrigerant being used. See Chapter 2.

The unit should be charged in the same manner described in Chapter 2 for adding refrigerant to the system. The exact charge required should be ascertained from the manufacturer, or from the identification plate on the unit. This exact charge should be placed



17-45. A charging board used for accurately charging hermetic systems.
(Airserco Mfg. Co.)

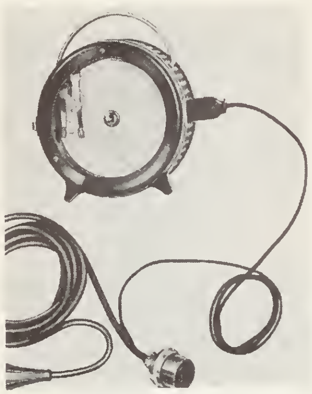
in a clean charging cylinder and then transferred into the system.

Figure 17-45 illustrates a practical charging board for accurately measuring the amount of refrigerant or oil charged into a system. This method provides greater accuracy than is possible if charging directly from a storage cylinder into the system. Remember to use clean lines, purged of all air, for transfer purposes.

17-29. TESTING THE UNIT

After the unit has been assembled, tested, evacuated and charged, it should be run with thermostatic control for at least 24 hours to ascertain its behavior. A recording thermometer is of great help during this operation to enable the repairman to know what is happening during the entire test period. Many service men neglect this very important part of repair work. Figure 17-46, shows a 72 hour temperature recorder.

The recorder is put in the refrigerator and it is connected to a wall plug and the refrigerator cord is then connected to the special socket on the cord, Figure 17-47. The chart is a three (3) day



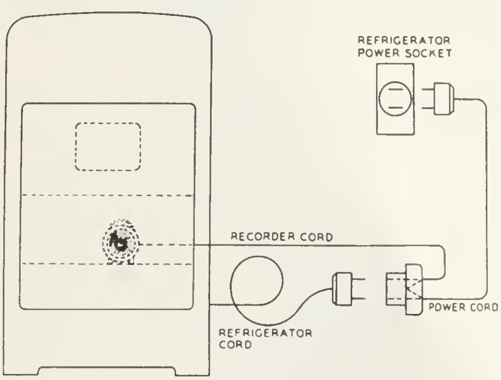
17-46. A recording thermometer. It records the temperatures and indicates the cycling intervals on a 72 hour basis.
(The Bristol Co.)

chart and it shows not only the cabinet temperature at all times but the other needle records the running times of the unit. If possible, the cabinet should be placed in a 100 F. room for this test.

If a cabinet is not used the cooling coil may be covered with a canvas bag to provide a load situation similar to what the unit will encounter in actual service. The testing room should be a quiet room in order to aid in checking for noise.

This testing should also include close observation of the temperature of the dome, the lines, and the even frosting of the cooling coil.

An ammeter and voltmeter or a wattmeter should be used to check the electrical section of the unit. See Chapter 7.



17-47. An installation diagram of temperature recorder.
(The Bristol Co.)

17-30. REVIEW QUESTIONS

1. Do all hermetic systems have service valves?
2. Which refrigerant is in most common use in hermetic units being built today (1955)?
3. Why are some of the condenser air passages controlled by ducts?
4. How many cooling coils are used in domestic refrigerator cabinets?
5. What happens to the suction line when a rotary compressor check valve leaks?
6. What causes tubing to create noise?
7. How may a motor-compressor dome be opened?
8. What is a good device to clean the outside of the mechanism?
9. How should the hermetic mechanism be prepared for moving?
10. What is the most popular method of sealing tubing joints in hermetic servicing?

Chapter 18

COMMERCIAL REFRIGERATION APPLICATION

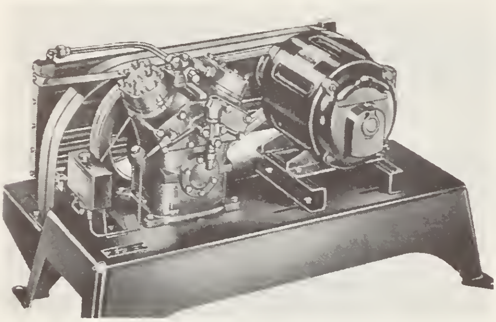
One of the broadest fields of refrigeration is that of commercial refrigeration. This field includes all automatic refrigerating mechanisms other than the domestic or household type; also the comfort cooling field. The field that sometimes is confused with commercial refrigeration is the industrial field. This latter field uses those refrigerating machines which need an attendant, usually a licensed refrigeration engineer, on the job constantly. Industrial plants are manually operated refrigeration machines and are commonly used for ice making, large storage houses, packing houses, industrial plants, and ice cream manufacturing plants. Only the commercial field will be studied in this chapter.

18-1. HISTORY OF COMMERCIAL REFRIGERATION

The first refrigerators used for commercial purposes were small semi-automatic ammonia machines. These machines were used for large meat markets and purposes of a similar nature. These appeared between 1913 and 1915 and filled a very definite need. The mechanism was not totally satisfactory, however, because the installation usually required that a competent refrigerator mechanic or engineer be on the premises, or the owner in some localities was required to have an operator's license. Also the cost of the mechanism was considered to be quite high. When the small domestic machines were first experimented with between 1916 and 1920 the possibility of using them for various commercial purposes was very quickly realized. Soon thereafter the first automatic refrigerators were produced for ice cream cabinets (1920-21). These quickly took the place of the old ice and salt mixtures previously used for ice cream storage. The Nizer Corporation of Detroit was one of the first successful manufacturers of this type of machine. This company merged later with Kelvinator, who continued the manufacture of these machines for a short time. The Frigidaire Corporation similarly produced products for this field, followed not long after by the Servel and Copeland companies. The second most important use for commercial refrigeration was for the water-cooling machine and the small automatic machines for grocery and walk-in refrigerator cabinets.

In 1923 mechanical refrigeration made its first real impression on this market, which has grown rapidly since that time. Also the various types of commercial refrigerating equipment

have increased and now include such installations as ice cream making, milk coolers, and beverage coolers. Figure 18-1 illustrates a water-cooled condensing unit suitable for commer-



18-1. A modern commercial condensing unit. It has a two-belt drive, a four-cylinder, V-type compressor, and a cleanable tube within a tube water cooled condenser. (Tecumseh Products Co.)

cial refrigeration. Although the future possibilities of commercial refrigeration are hard to predict, the leaders of the industry are very optimistic as to its future.

18-2. SCOPE OF COMMERCIAL REFRIGERATION

The commercial refrigeration field covers a multitude of applications.

It is used for the long storage or short storage, or display of the following:

Fresh foods:
1. Meats
2. Vegetables
3. Fruits
4. Candy
5. Poultry

It is used for freezing or storing the following:
1. Meats
2. Vegetables
3. Fruits
4. Poultry
5. Ice Cream

It is used for cooling water for:
1. Drinking
2. Air conditioning
3. Machine Tools
4. Heat treatment

It is used for storage or display of:
1. Milk
2. Bacteriologicals

The cabinets are usually made of steel inner and outer shells, reinforced with steel or wood frame and insulation installed between the shells.

The cabinets used for display are built with windows or are open at the top for display and easy access.

Another way to classify commercial refrigeration is by the commercial businesses that use the equipment. This classification is as follows:

Grocery Stores:
- Reach-in Cabinets
- Display Cases
- Ice Cream Cabinets
- Frozen Food Cases

Meat Markets:
- Walk-in Cooler
- Reach-in Cabinet
- Display Cases

Super Markets:
- Walk-in Cooler
- Reach-in Cabinet
- Closed Display Cases
- Open Display Cases
- Frozen Food Cases
- Frozen Food Display Cases

Restaurants:
- Walk-in Coolers
- Reach-in Cabinets
- Frozen Food Cases
- Water Coolers
- Beverage Coolers
- Ice Cream Cabinets
- Ice Makers
- Salad Pans

Drug Stores:
- Ice Cream Cabinets
- Bacteriological Cabinets
- Soda Fountains
- Water Coolers

Farm Cabinets:
- Freezers
- Frozen Food Cabinets
- Milk Coolers

Locker Plants:
- Chill Rooms
- Aging Rooms
- Fast Freezers
- Frozen Food Storage
- Frozen Food Display Cases

Trucks

Ice Cream Parlors

Frozen Custard Stands

Metal Working Plants:
- Heat Testing
- Machine Coolants

Bakeries:
- Dough Retarding

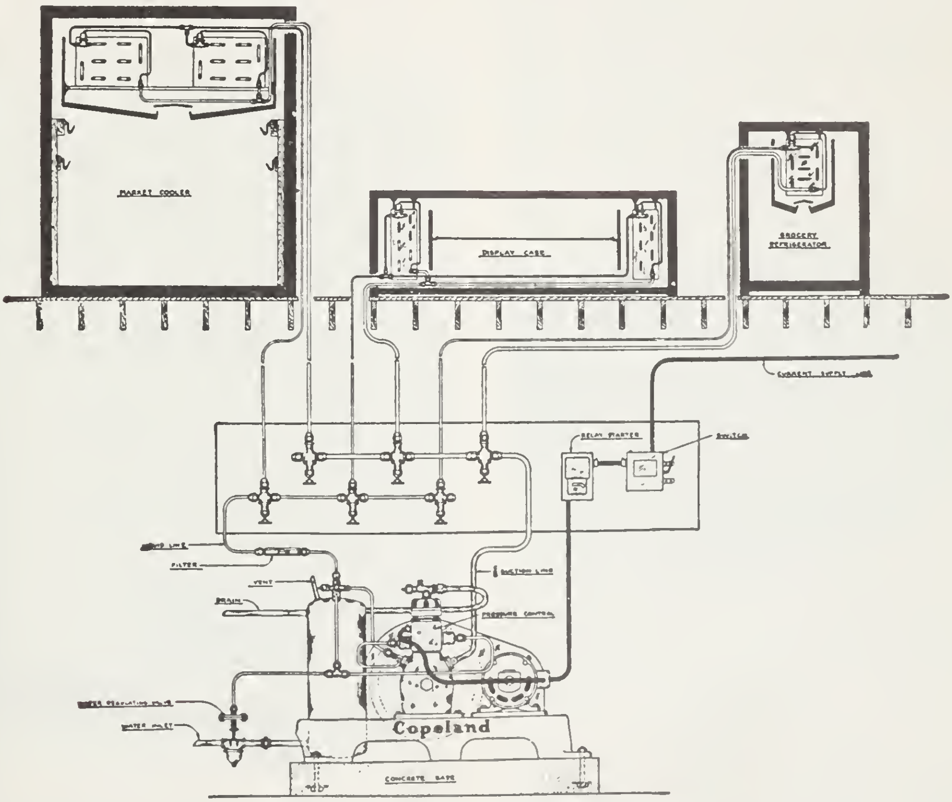
Fur Storage

The three main differences between the domestic and commercial refrigeration machines are:

1. Multiple installations, that is, the same condensing unit may be connected to two or more cooling coils.
2. Water-cooled condensers and compressor heads are commonly used.
3. The commercial machines on the average are larger than the domestic machines, and are made up to as much as 25 tons of refrigeration capacity.

The mechanism in brief is very similar to the domestic mechanism and includes:

a) compressors
b) condensers
c) liquid receivers
d) cooling units
e) refrigerant controls



18-2. A typical non-code commercial installation.
(Copeland Refrigeration Corp.)

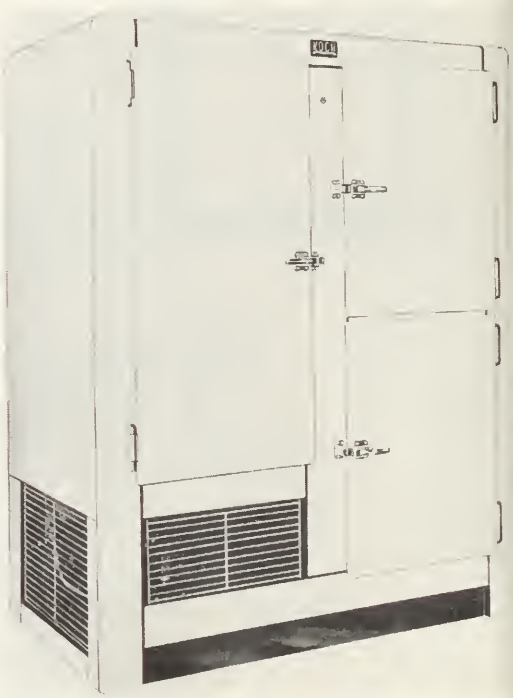
f) servicing valves
g) motor controls
h) multiple valves
i) motors
j) water valves

Figure 18-2 illustrates a typical non-code commercial installation. This installation involves a water-cooled compressor and condenser, driven by a 1 H.P. motor and cools a walk-in box, a display counter, and a grocery box. As shown, the system has three cooling coils and one condensing unit. To be water-cooled the condensing unit must be connected to a water supply. An automatic water valve regulates the flow of water. The motor will probably be connected to the local power system through a starting relay and must be installed according to code. A suction line of $\frac{1}{2}$-inch or 5/8-inch O.D. in conjunction with a 1/4-inch O.D. liquid line are run to these cooling units. Shut-off valves are located at the junctions of the cooling coil lines to the main suction and liquid lines. These are finned natural convection cooling coils using thermostatic expansion valves.

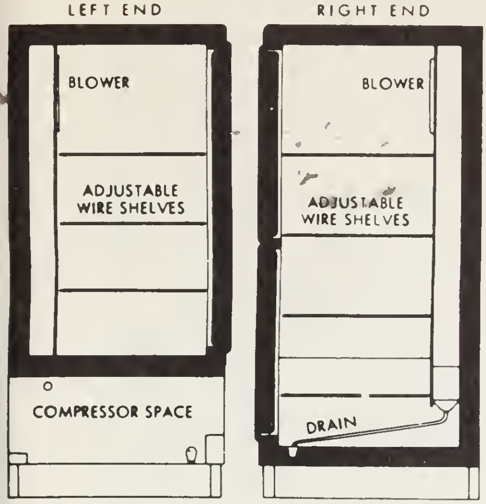
Two kinds of refrigerant controls are suitable for use in multiple installations. These are the low side float and thermostatic expansion valve. Manifolds with hand shut-off valves are recommended in these installations.

18-3. COMMERCIAL CABINET CONSTRUCTION

Inasmuch as commercial refrigeration covers a considerable number of applications, a study of the various cabinets used in these applications is necessary. There are many different sizes, shapes, and styles of cabinets used for a number of different applications. Some classifications are: grocery cabinets; grocery display counters; walk-in boxes for storage purposes, fresh meat preservation and for beverage and milk storage purposes; display counters for meats of all kinds, including a special type for fresh fish, also a type which uses the lower part of the display counter for storage purposes; apartment house refrigerator cabinets; ice cream cabinets; soda fountains in which compartments of different temperatures are maintained; water-cooler cabinets or fountains which must have a peculiar style of construction to facilitate insulation; motor trucks whose bodies must be of insulated construction to produce economy of refrigeration; and railway trains of refrigerated cars of special refrigeration construction. The display of very cold or frozen foods is a new and ever increasing application of commercial refrigeration.



18-3. A reach-in cabinet with a self-contained condensing unit mounted in the lower left section. (Koch Refrigerators, Inc.)



18-4. A cross section of a reach-in cabinet.
(Koch Refrigerators, Inc.)

18-4. GROCERY CABINETS (REACH-IN-CABINETS)

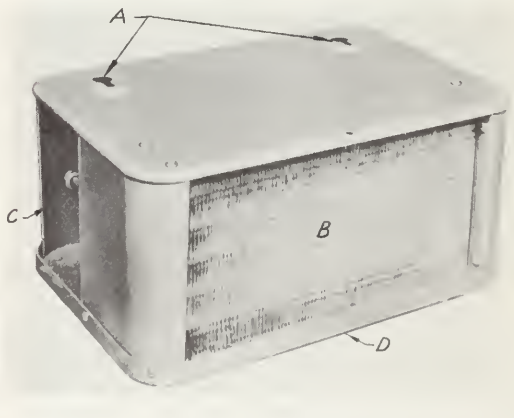
Grocery cabinets have been used for many years to keep perishable produce and groceries at satisfactory temperatures. Early cabinets used ice as the means of refrigeration, but thousands of these have been converted into mechanical refrigeration cabinets since the advent of mechanical refrigeration. These cabinets are usually of the reach-in type with small doors opening so that one may gain access to any shelf inside the box. Some of these doors are fitted with windows. The number of doors varies from two up to eight. See Fig. 18-3. The internal construction of this cabinet is shown in Figure 18-4. A blower cooling coil is mounted on the back wall and a drainage tube is installed at the lower end of the blower casing.

The space which contains the cooling unit is usually called the bunker. This terminology comes from the original use of ice in these cabinets. These bunkers are sometimes located in the upper left hand corner of the box, or in the upper right hand corner and sometimes completely across the top of the inside of the cabinet. This latter type sometimes uses a door located at the end of the cabinet for access to the bunker. Blower type cooling coils are now used extensively for grocery cabinets.

The coil is usually located in the upper center of the cabinet; the old flooded coils used a few deep fins while the new coils are deep finned $1\frac{1}{2}$-inch spacing coils, using a thermostatic expansion valve. The coils are suspended from the top, Figure 18-5.

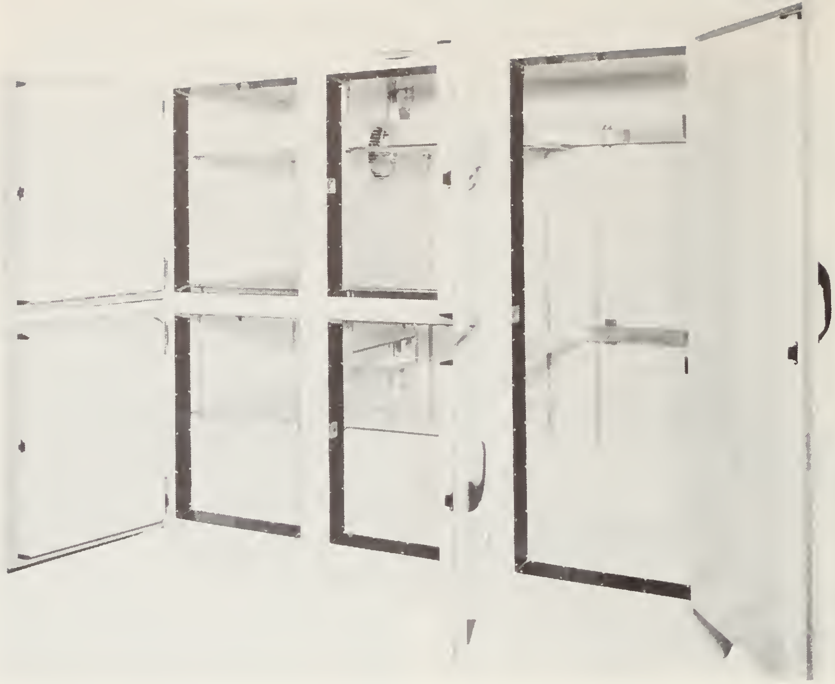
The early box construction was hard wood, oak, maple or similar wood on the outside. The later models are constructed with a porcelain exterior. While the inside of the early cabinet used spruce or some other similar wood as a lining, the modern models have porcelain linings. The insulation most commonly used for these boxes is two inches of slab cork. Early cabinets used moisture-proof paper and dead air spaces.

The size of these boxes varies considerably, with 10 to 15 cubic feet



18-5. A blower type coil. A. Hanger key hole slots; B. Air inlet; C. Cooled air outlet (one on each side); D. Drain pan
(McQuay, Inc.)

interior net volume being quite common. The temperatures desired are the same as in domestic boxes with a



18-6. A reach-in cabinet designed to store and refrigerate a variety of foods.
(McCall Refrigerator Corp.)

minimum of 35 F. and a maximum of 45 F.

A reach-in cabinet that is popular for smaller grocery stores and markets is shown in Fig. 18-6. It has four half doors and one full height door. The cooling coil is the blower type and is mounted in a vertical position perpendicular to the half doors. This circuit uses a remote condensing unit. The full height door permits storing beef quarters, etc.

18-5. WALK-IN COOLERS

Meat markets usually have a refrigerated cabinet or walk-in cabinet in which to store meat and other perishable products. These cabinets have large doors and windows and are sometimes classified as butcher boxes. The size of these cabinets varies to quite an extent, but two heights are standard; 9 feet 10 inches and 7 feet 6 inches exterior dimension. These boxes are called the "knock-down style" which means that they may be taken apart for ease in removing.

Some standard walk-in cooler sizes are:

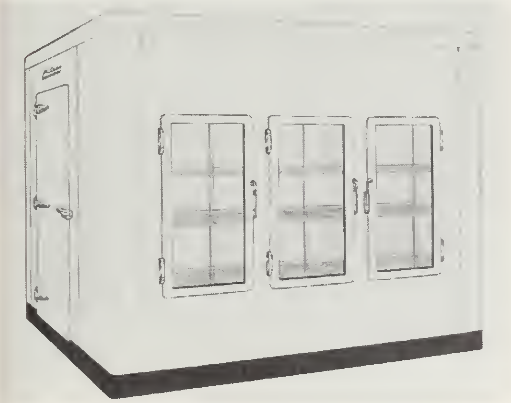
L.	W.	H.
7'	5'	9'10"
8'	6'	9'10"
8'	8'	9'10"
9'	7'	9'10"
12'	10'	9'10"
6'	5'	7' 6"
6'	6'	7' 6"
7'	6'	7' 6"

Early walk-in coolers were made with oak, maple, or other hard wood exteriors, and spruce linings. The insulation consisted of three to four inches of cork placed between the inside and outside surfaces, Fig. 18-7. At present these boxes are being made with metal linings and porcelain finished exteriors. The door is usually made of the same construction as the box and is gasketed to make it air-tight. These gaskets are usually made of built up rubber. Door latches for these cabinets must also be accessible from the

inside.

In addition to the entrance doors, these boxes are equipped with small reach-in doors, usually with double or triple glass. That is, instead of having a cork lining, these doors have two or three panes of glass arranged in such a way that they are air-tight, and for one or two air spaces respectively between them. Plate glass is usually used; special chemicals, such as calcium chloride, are used to keep the spaces between the panes free from moisture.

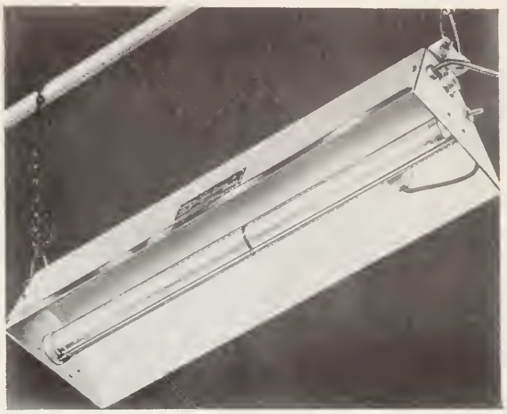
The cooling unit for these boxes is usually mounted overhead inside the cabinet, with a baffle constructed to



18-7. A walk-in cooler of steel construction.
(McCray Refrigerator Co., Inc.)

promote good air circulation around it. An overhead bunker door is provided in the older models to permit access to this space. Its size is standardized at 27 inches wide minimum and 28 to 36 inches high. Some of these walk-in coolers have a side mounted cooling unit which has a vertical baffle located between it and the main portion of the cabinet interior. Forced convection cooling units are also used in these cabinets, as such an installation eliminates any need for a baffle.

The temperature maintained in this type of cabinet depends upon the use. For meat storage or fresh produce storage, a temperature of between



18-8. An ultra-violet ray lamp used in refrigerators to minimize bacteria growth.
(Ultra Violet Products, Inc.)

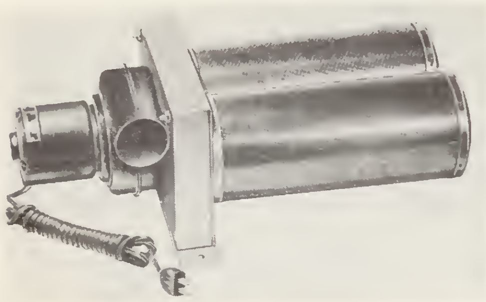
35 F. and 40 F. is essential and a relative humidity of about 80 per cent should be kept. A certain air movement is necessary to prevent mold, etc.

18-9. An ultra-violet lamp being used in a refrigerator cabinet.
(Ultra Violet Products, Inc.)

Ultra-violet lamps are also used to keep bacteria and mold growth to a minimum. See Figure 18-8 and Figure 18-9. An 18'' tube will give good protection to a cabinet 10 x 10 x 12. Another method of cleaning the air and reducing mold and bacteria is to use an activated carbon filter, Fig. 18-10.

For milk storage, beer cooling, and other service in which the dehydration

of foods is not important, colder temperatures may be used as desired and less attention may be paid to relative humidity. The natural convection cooling coils used in these cabinets usually

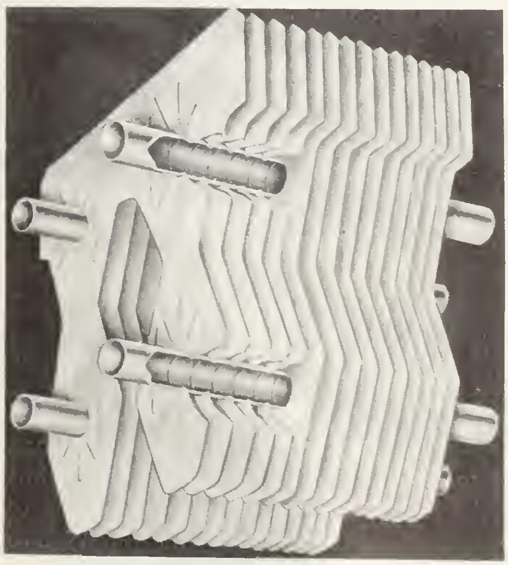


18-10. An activated carbon filter used for cleaning air in a refrigerator cabinet.
(W. B. Connor Engineering Corp.)

use 1/2-inch fin spacings and vary between 6 inches to 16 inches in depth, Fig. 18-11.

18-6. FLORIST CABINETS

Florists' cabinets vary in size and construction; they differ from grocery



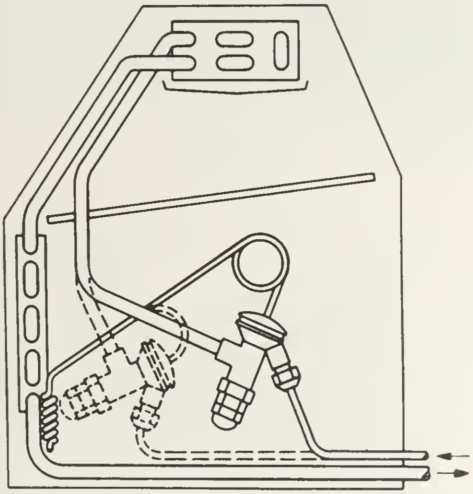
18-11. A finned natural convection cooling coil.
(Frigidaire Div., General Motors Corp.)

cabinets and walk-in coolers in three ways. First, the temperatures within the cabinet may be kept much higher than those in the other types of boxes. Temperatures between 55 F. and 58 F. are quite common. Second, the thickness of the insulation for these cabinets, as a result of the lesser temperature difference, is usually but 1 to 2 inches thick. Third, these cabinets are made with an extensive amount of window surface, permitting an easy

18-12. A florist's display refrigerator.
(McCray Refrigerator Co., Inc.)

18-13. An activated carbon air filter installed in florist cabinet. Also, note the cooling coils, the hangers and the drains.
(W. B. Connor Engineering Corp.)

display of cut flowers within the cabinet, Fig. 18-12. Humidity is an important factor in a florist's cabinet, and should be kept as high as possible in order to retard evaporation from the surface of the leaves and flowers. Many florist cases uses odor-removing devices to prevent contamination of the flowers. An activated carbon filter is popular because it reduces mold growth, neutralizes ethylene and extracts the gases and odors given off by the flowers, Figure 18-13.



18-14. Cross section of glass enclosed display case. (Detroit Controls Corp.)

18-7. DISPLAY CASES

To display produce to the best advantage, stores frequently use refrigerated counters. These counters are equipped with glass fronts, enabling the purchaser to see the array of articles handled by the merchant; at the same time this food is safely refrigerated. This refrigeration is necessary to prevent the spoiling of the food during the 8 to 10 hour period that it is stored in the display case. Electric lights for lighting display cases are usually installed outside of the glass of the case in order that the heat generated by the lights will not increase the refrigerating load.

There are several different types of display cases. These cases vary as to design, length and height. There are three basically different types:

1. Glass enclosed display case only.
2. Glass enclosed display case and storage cabinet.
3. Open display cases.
   a. For fresh produce
   b. For frozen foods.

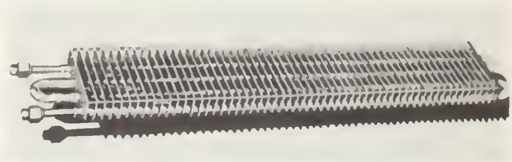
Display cases are sometimes classified as to the location of the cooling coil:

1. Rear bunker display case
2. Overhead bunker display case
3. End bunker display case

The rear bunker display case is a modernization of the old display case that used cracked ice in a sheet metal trough at the rear of the cabinet. It is not used anymore.

18-8. SINGLE DUTY CASE

A very popular display counter is the type using an overhead cooling coil. This counter frequently makes use of the space below the display portion as a refrigerator cabinet, Figure 18-14. This counter has the main cooling coils mounted in the upper portion of the display space just underneath the shelf which forms the top of the counter. This naturally gives very good refrigerating temperatures all the way through the display space, Fig. 18-15.

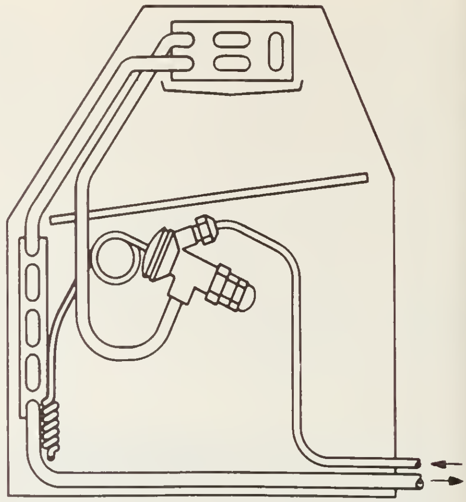


18-15. A shelf cooling coil. Aluminum fins and copper tubing are mechanically bonded together. The fins are offset. (Peerless of America, Inc.)

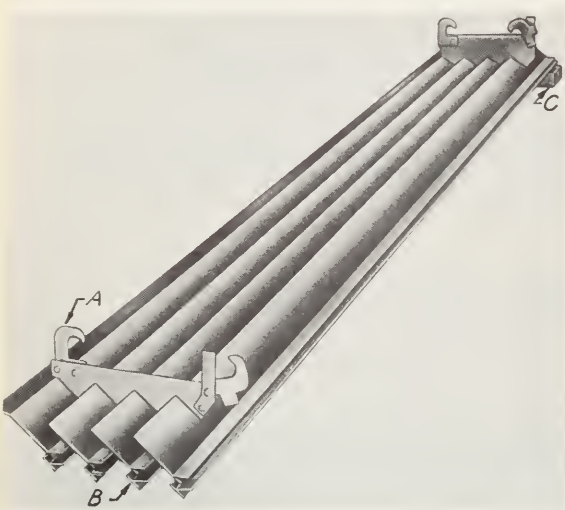
In addition, some of this type counters have shelf coils. They are called auxiliary cooling coils. These cooling coils are located just underneath the shelves; they consist of coils of tinned tubing containing evaporating refrigerant so placed that each shelf is individually cooled, Fig. 18-16.

18-9. DOUBLE DUTY CASE

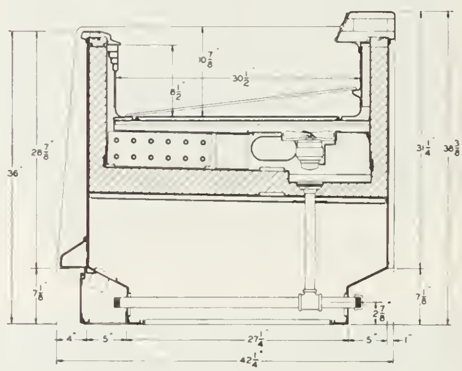
Many models have storage space beneath the display portion of the counter which is also refrigerated; its cooling coil is usually connected in



18-17. A double duty display case using two cooling coils. 2 One thermostatic expansion valve is used for both coils.
(Detroit Controls Corp.)



18-16. A display case cooling coil drain pan. It is compact, permits good circulation and condensate drainage. A. Hangers; B. Individual baffle drains; C. Collector drain.
(Peerless of America, Inc.)

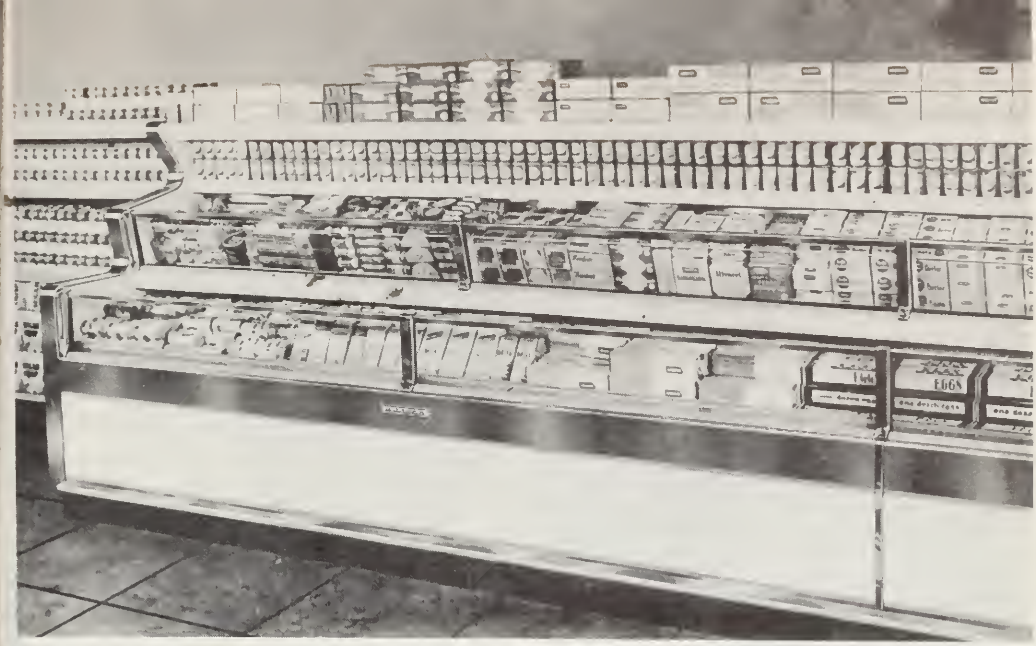


18-18. Cross section of an open meat display case. Note the cooling coil location, the blower and the drain.
(Tyler Refrigeration Corp.)

series with the coils above. The temperatures maintained may be kept at 40 F. to 45 F. in both compartments, or warmer if desired, because they are only temporary containers for the food or produce as it should be transferred to the walk-in storage cabinet overnight. The coils used in these installations must necessarily be very narrow and they are made with fins as small as $1\frac{1}{4}$ inches in width, Figure 18-17. Some of the shelf coils are the plain tubing type. Many of these display cases are now using blower coils for cooling. These coils take little space and provide even refrigeration temperatures throughout the display case.

18-10. END COIL DISPLAY CASE

Another type of display counter used to some extent is the end bunker type. Instead of using cooling coils running the full length of the counter,



18-19. Open type refrigerated display case.
(The Warren Co., Inc.)

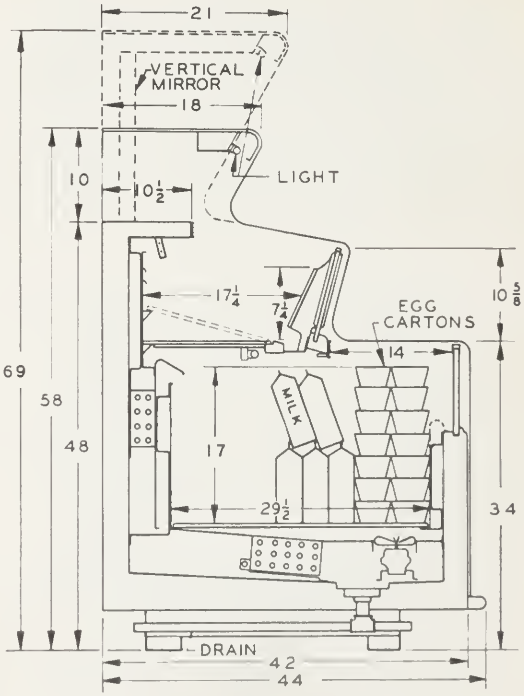
the coils are located at each end. If the counter is seven feet long or less, it may have but one bunker at the end. It usually has coils at both ends if the counter is longer. These counters vary from 35 to 45 inches in height and the glass extends to the floor. The space within usually contains from two to four shelves which may be viewed either from the front or the top of the case. Sometimes the glass is inclined in front, but more often is vertical. The temperatures that are kept in these counters are between 40 F. and 50 F. A coil similar to the grocery cabinet coil is used in these cases, or blower coils may be used.

18-11. OPEN DISPLAY CASE

To make foods more accessible to customers in self-service markets, open display cases are in common use, Fig. 18-18.

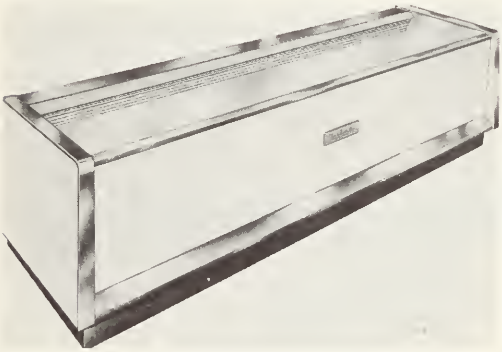
These cases may be designed with or without storage space in the base of the unit. The case has storage space open at the top and with walls or the upper part of the wall enclosed in double or triple glass panes.

The higher temperature cases such as for fresh meats, dairy products,



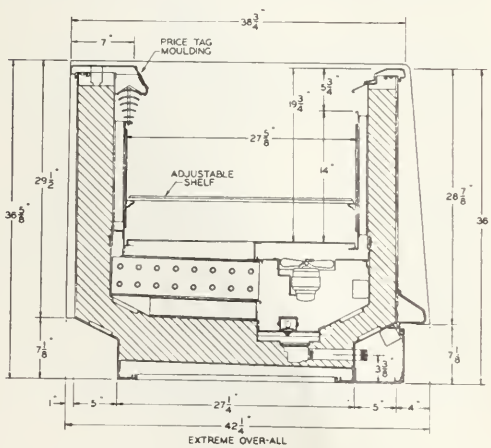
18-20. A cross-section of an open-type dairy products case.
(The Warren Co., Inc.)

etc., do not present any special cooling coil problems. Blower cooling coils are used and ducts flow the cold air through grilles at the rear of the case at the same level as the refrigerated foods and the warm air return is down the front of the case, Fig. 18-19. The details of this case are shown in Fig. 18-20.

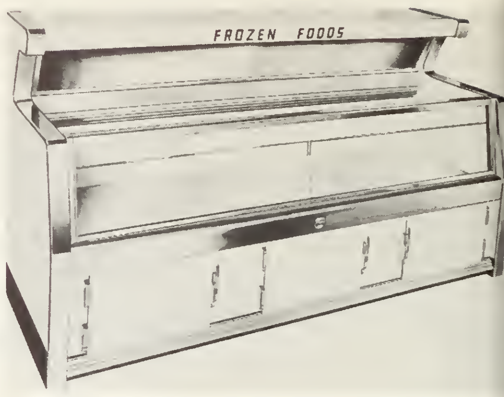


18-21. An open frozen foods display case. (Tyler Refrigeration Corp.)

The low temperature units for displaying frozen foods present a difficult coil defrosting problem. The coils must be defrosted at least once a day. The defrosting is done as quickly as possible to prevent the case from warming up too much. The defrosting must be done



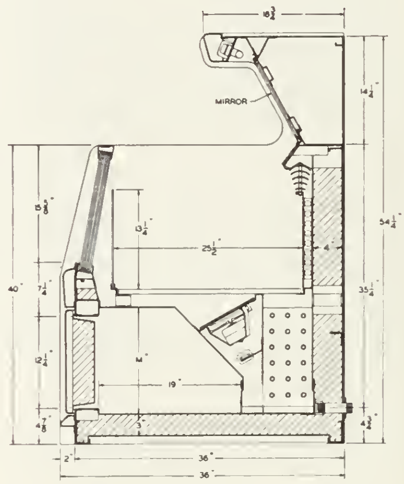
18-22. The construction details of an open frozen foods display case. (Tyler Refrigeration Corp.)



18-23. An open type frozen foods display case. (Tyler Refrigeration Corp.)

automatically. A time clock is frequently used and it operates a hot gas defrosting system or an electric heater defroster device. See Chapter 19 for details of these systems.

An open display case for frozen foods is shown in Fig. 18-21. Its construction is shown in Fig. 18-22.



18-24. A cross section of an open frozen foods display case. Note the blower fan and the lower storage doors. (Tyler Refrigeration Corp.)

18-12. OPEN FROZEN FOOD DISPLAY CASE

The storage and display of frozen foods has become very popular. These

cabinets represent a new problem. The display cases, either open or closed, have to maintain temperatures near 0 F., Figure 18-23 and Figure 18-24. The coils therefore must operate at -10 F. to -15 F. These coils have to be defrosted frequently. Heater wires are installed along the parts of display cases that may collect condensation from the air. These heater wires are fastened with a mastic.

Storage cabinets and closed display cases are constructed in both the chest style and upright cabinet type. Because of the low temperatures in these cabinets, the insulation is thicker, the openings are better gasketed or sealed, and the insulation is more carefully hermetically sealed. The chest type is very popular because the top openings prevent the spillage of the cold air when the cabinet is being used.

18-13. FROZEN FOOD STORAGE CABINET

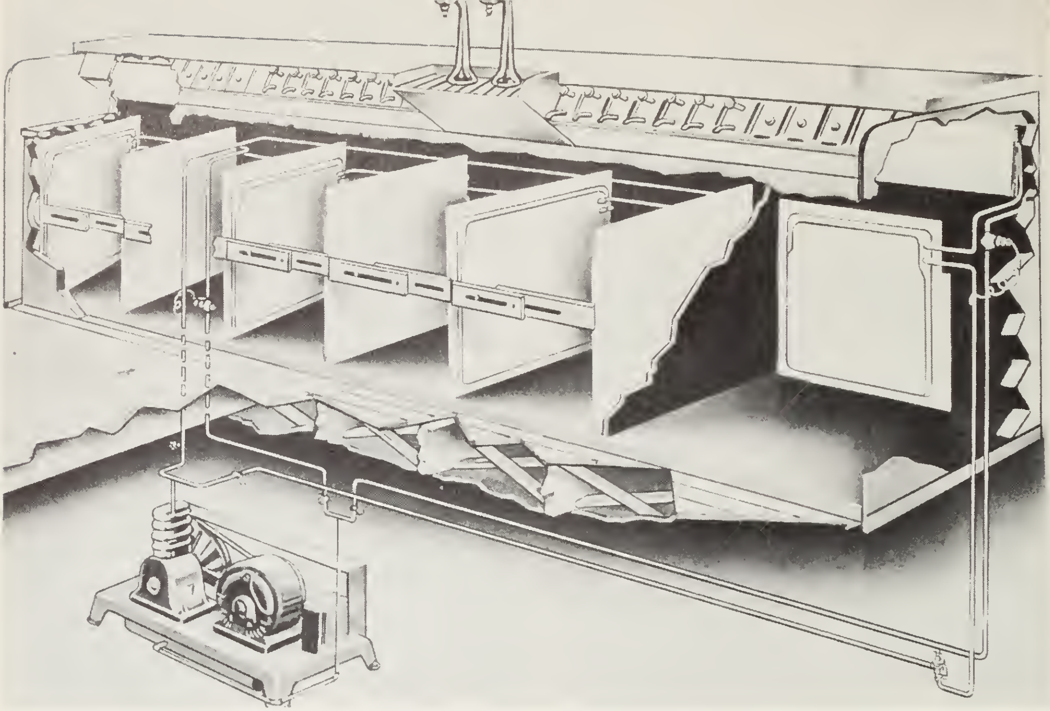
The frozen food storage cabinet may be either a chest type or an upright type cabinet with very thick insulation, 4 to 6 in. hermetically sealed. The doors or access openings are also heavily insulated and are usually provided with a double gasket. These cases are used for storage purposes only and the food is moved from these cases to the display cases as needed. These cabinets operate at 0 F. Due to the low temperature at which these cabinets operate, many of them are fitted with an electric warming coil around the door to keep it from freezing closed.

18-14. FAST FREEZING CASE

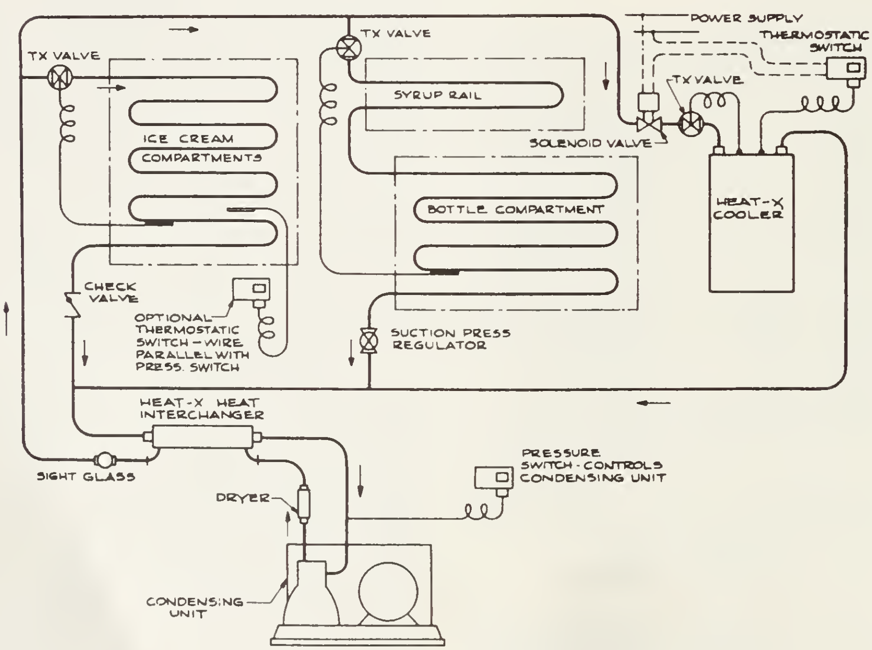
Cases used for freezing foods rapidly to a frozen condition are very similar to the storage cases except that the temperatures are maintained at about -20 F. and the food is placed as close to the freezing plates as possible. Some cases use refrigerated shelves to provide more heat transfer surface. These cases are popular on farms and in locker plants.

18-15. ICE CREAM CABINET

Ice cream cabinets, since their inception, have been made of a steel frame-work with a sheet metal exterior, insulated with cork and containing either a brine tank or dry coils surrounding the ice cream sleeves. The size of the ice cream tank holders, or sleeves as they are called, is standardized; therefore the construction of the various makes of cabinets is very similar. The insulation is usually four inches thick, except on the top, which is commonly two inches thick. Slab cork is the most popular insulation and is very carefully sealed with hydrolene. Some ice cream cabinets are self-contained, meaning that the refrigerating machine or condensing unit is built into one end of the cabinet, and some of them are of the remote type. The size of these cabinets is based on the number of sleeves required to contain bulk ice cream cans. They range from one to twelve sleeves. The temperature at which the ice cream should be kept is between 10 F. and 0 F. The -10 F. is for brick ice cream which may be stored in these sleeves and 0 F. is best for bulk ice cream. If the temperature is too cold, the ice cream becomes too hard to serve easily; it also tends to become crystallized. The cooling units in the past were of the low side float type submerged in brine, which surrounded the sleeves keeping the ice cream cold. However, this was too bulky and inconvenient in many respects so present models use dry cooling coils. Some of the coils consist of tinned tubing wrapped around and soldered directly to the sleeves. Other coils consist of sheet metal with



18-25. A typical soda fountain cabinet refrigeration installation. Note the two thermostatic expansion valves and the two temperature valves.
(Dole Refrigerating Co.)



18-26. A complete soda fountain cycle diagram. Note the solenoid valve and the suction pressure regulator and how these valves are used to control temperatures in various parts of the installation.
(Bush Mfg. Co.)

refrigerant passages formed in the metal. The sleeve covers, that is, the tops to the sleeves which must be raised in order to gain access to the ice cream, are also standardized by the manufacturers. Having the openings to these sleeves at the top prevents the spilling of cold air from the cabinet, when opened, and is an easy way of access.

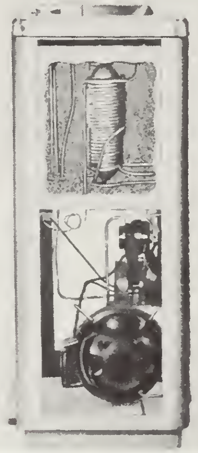
18-16. SODA FOUNTAIN

Soda fountains are a very compact unit for storing and dispensing of ice cream, water, beverages, syrups, and ice. They are usually of beautiful construction and are designed to facilitate dispensing. The fountain usually has an ice cream cabinet of typical design built into it. Another portion of the fountain contains the water-cooling mechanism which must be designed to maintain correct water temperatures; usually the return of refrigerant gas from the ice cream cabinet and the drinking water cooler is passed around the syrups, maintaining them at a relatively cool temperature. The beverages are kept at the same temperature as the water. Soda fountain construction is very compact. As a result, soda fountains are often very difficult to service due to lack of space in which to work.

The syrups should be maintained about 45 F., the water anywhere from 32 to 50 F., and the ice cream as mentioned, between 0 F. to 10 F. A two-temperature valve is almost a necessity in this type of installation. Figure 18-25 shows a typical soda fountain cabinet refrigeration installation.

A cycle diagram of a complete soda fountain that is refrigerated by one condensing unit is shown in Figure 18-26. The soda fountain consists of an ice cream compartment, a syrup rail, a bottle compartment, and a beverage cooler. Thermostatic expansion valves are used; the ice cream coil has a check valve, the syrup coil and bottle compartment coil are controlled by a two-temperature valve, while the beverage cooler has a solenoid liquid line shut-off valve. Note the sight glass, the heat exchanger, and the dryer mounted in the refrigerant lines near the condensing unit.

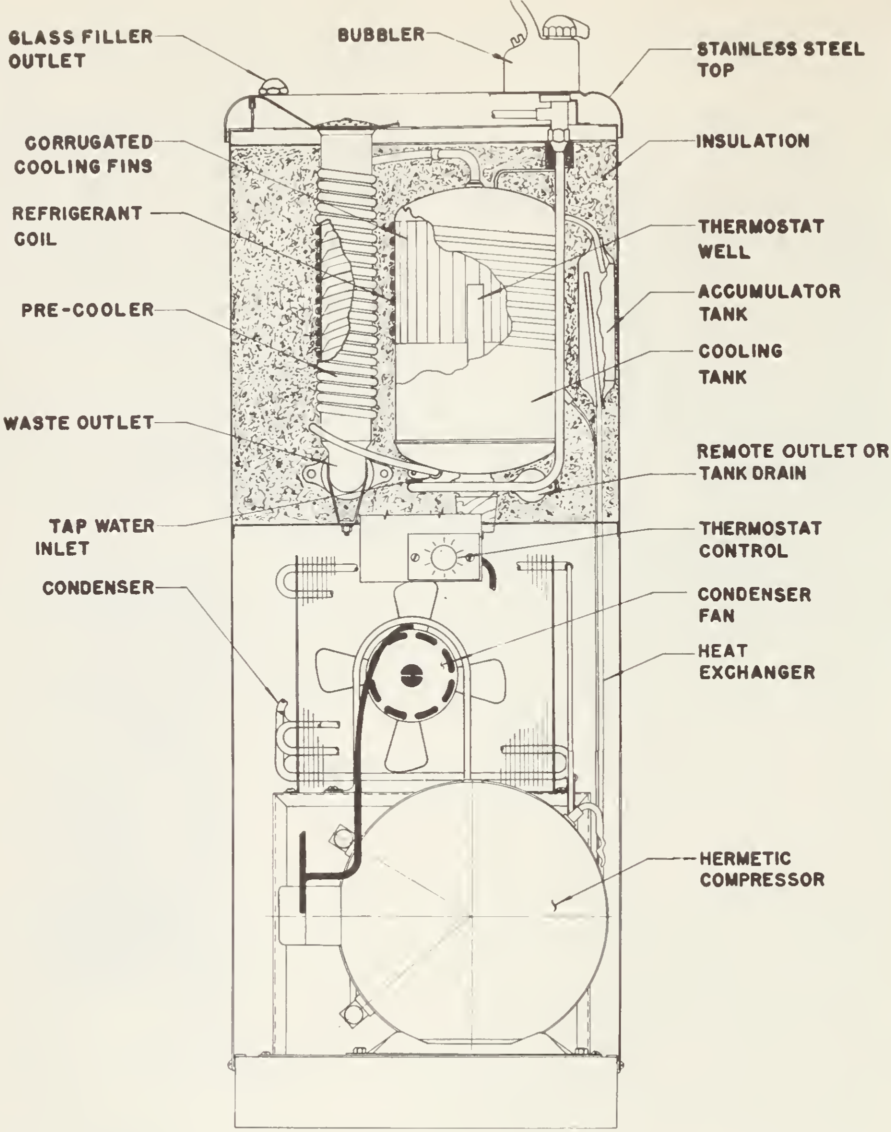
A bobtail soda fountain is the same as the one illustrated except the ice cream cooling coil is not used.



18-27. A self contained water cooler. (Temprite Products Corp.)

18-17. WATER COOLER

There are really no cabinets used for the containing of water-cooled mechanisms in the strict sense of the word. The so-called cabinet is a sheet metal housing built around a steel framework, to give a pleasing appearance to the fountain. Inside this sheet metal housing is usually constructed the condensing unit, located near the floor, and above this is the water-cooling mechanism. This latter is the only part insulated from the room. The insulation is usually a specially formed slab cork between one and one-half

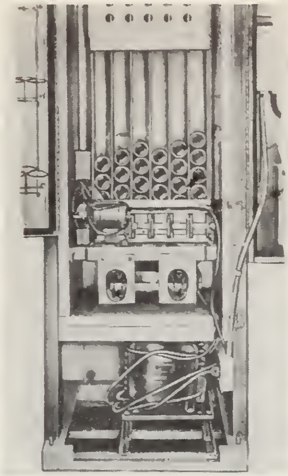


18-28. A diagram of a self-contained water cooler.
(Ebco Mfg. Co.)

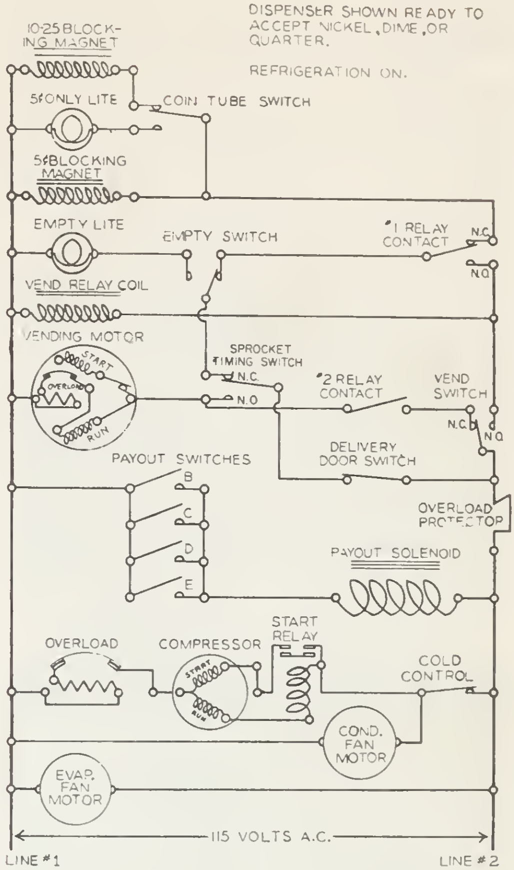
inches and two inches thick. These cabinets are made in such a way that one or more sides may be easily removed to gain access to the interior, Fig. 18-27. Water-coolers frequently use heat exchangers. These make use of the low temperature of the waste water and the suction line to pre-cool the fresh water line to the cooling coil.

Individual coolers are of the bottle cooler type or designed to connect to the plumbing system. The bottle cooler type uses five-gallon bottles of water mounted inverted on the top of the cabinet. Overflow and drain water are stored in a container built into the cabinet below the top. These coolers use air cooled condensing units exclusively. They are used where water and drains are not available or where the plumbing installation may be expensive.

Those water coolers using a plumbing supply and a drain connection, must be installed according to the National Plumbing Code and the local code. See Fig. 18-28. The plumbing



18-29. A bottle beverage refrigerated dispenser. The cabinet doors are open showing the interior structure. (Mills Industries, Inc.)



18-30. The wiring diagram for a refrigerated bottled beverage coin-operated dispenser. (Mills Industries, Inc.)

should be concealed. A hand shut-off valve is required in the fresh water line. The drain pipe must be at least the $1\frac{1}{2}$ in. size. The bubbler opening must be above the drain in such a way as to eliminate the chance for accidental syphoning the drain water back into the fresh water system.

The temperatures of the cooling water are variable depending on the wishes of the persons who are drinking the water. For laborers in heavy working conditions 50 F. to 55 F. is cold enough. REFER TO PARAGRAPH 21-28 FOR RECOMMENDED TEMPERATURES. One must be careful to use clean materials for the water passages.

In large business establishments, in office buildings, or in factories, the multiple water-coolers, instead of individual ones, are the most popular. These coolers have one large condensing unit supplying many bubblers and these are of many different constructions.

The basin of the water cooler is made of porcelain coated, cast iron, porcelain coated steel or stainless steel.

18-18. BEVERAGE COOLER

A very popular application of refrigeration is the cooling of bottled beverages. Most people are familiar with the automatic bottle dispensers (coin operated). These units contain a refrigeration system. The system is hermetic and usually has blower type cooling coil to cool the bottles. The automatic bottle handling devices are powered by a separate motor.

The bottled beverage units are available in several designs. Some dispense only one beverage while some can dispense several different kinds of beverages. Figure 18-29 illustrates a

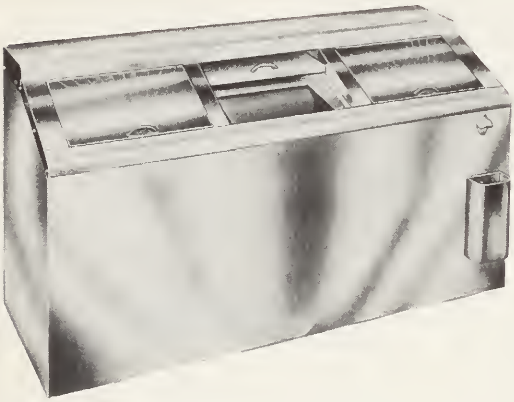
bottle unit with the doors open and the condensing unit front cover removed.

The coin unit is in the right door while extra bottles are stored in the left door. The condensing unit is located in the bottom of the cabinet while the blower cooling coil is mounted behind the two-bottle chute openings.

The automatic operation of this unit with its vending motor, magnets, signal lights, relays, etc. necessitates a wiring system, Fig. 18-30.

Many commercial establishments use special cabinets for cooling bottled beverages, Fig. 18-31. These cabinets also use blower type cooling coils, Fig. 18-32.

A blower coil that is very compact (as small as 7 x 9 x $9\frac{1}{2}$ in.) and is

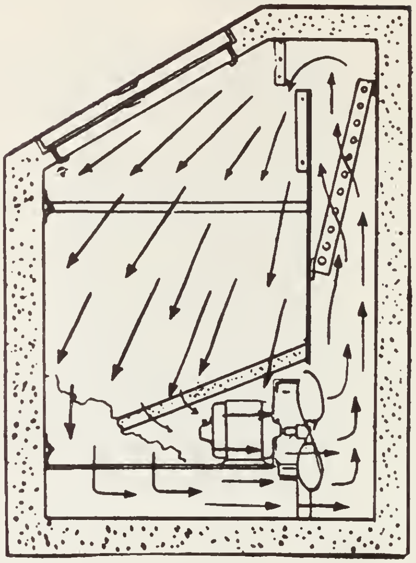


18-31. A dry bottled beverage cabinet. This unit is called a three-door model. It uses a remote condensing unit.
(National Cooler Corp.)

used in beverage coolers, soda fountains, vending machines, etc., is shown in Fig. 18-33. This coil has a circular finned coil. It is known as a "pie plate" coil.

18-19. AUTOMATIC ICE MAKER

Many commercial establishments have need for ice. Ice cube makers for many years used ice cube trays and shelf cooling coils placed either in separate reach-in cabinets or in back-

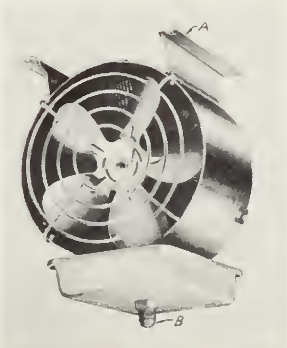


18-32. A cross section of a dry bottled beverage cooler. It has a forced convection cooling coil.
(National Cooler Corp.)

bar storage units. They were either self-contained mechanisms or connected into multiple installations.

The cubes manufactured in these ice cube trays however were cloudy due to entrapped air in the ice.

Automatic ice makers are now on the market. These units automatically control the water feed, automatically freeze the water into ice, empty the ice into storage facilities, and finally stop when the storage space is full.



18-33. A cylindrical blower coil complete with hangers (A) and drain (B). This unit is used in soda fountains, beverage coolers, vending machines, etc.
(Peerless of America, Inc.)

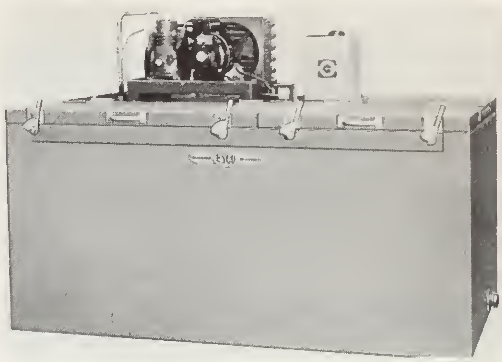
There are a number of different type units on the market. Floats and solenoids are used to control the water flow. Weight switches are used to operate the storing action when the ice is made. Removal of the ice from the freezing surfaces is accomplished by using electrical heating elements, hot gas defrosting, or mechanical ice removal.

18-34. An automatic ice cube maker with the unit above and the storage bin below.
(York Corp.)

These units use as much as 5 in. of insulation and use condensing units up to 3/4 H.P.

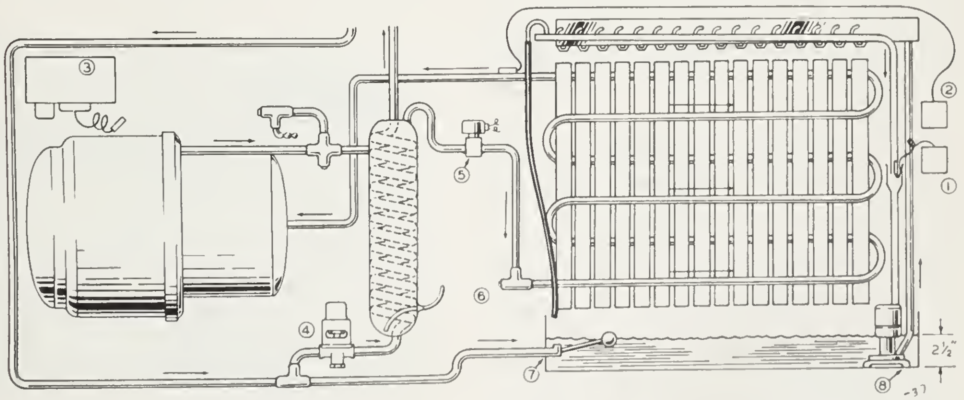
An ice cube maker with a capacity of 8,000 ice cubes per twenty four hours or about 450 pounds of ice each day is shown in Fig. 18-34.

Its refrigeration mechanism is shown in Fig. 18-35. Water flows through vertical stainless steel tubes and when a hollow square length of ice is formed the refrigeration stops, hot gas defrosting starts and as the long



18-36. An immersion type dairy milk cooler. Note the condensing unit on the left and the water pump motor housing and control.
(Esco Cabinet Co.)

① T-1 OVERFLOW THERMOSTAT
② T-2 SUCTION LINE THERMOSTAT
③ COMBINATION BIN SAFETY THERMOSTAT & H P CUT-OUT
④ CONDENSER WATER REGULATING VALVE
⑤ HOT GAS SOLENOID VALVE
⑥ RESTRICTOR TUBE
⑦ MAKE-UP WATER VALVE
⑧ WATER RECIRCULATING PUMP

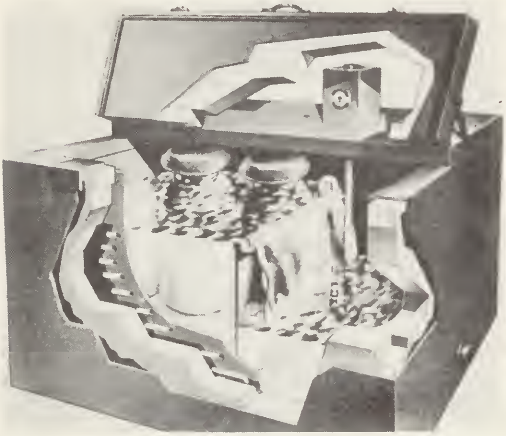


18-35. A schematic view of an automatic ice cube maker. Some of the water is used to cool the condenser while some of it is used to make ice cubes.
(York Corp.)

square rods of ice slide down the tubes they are cut into cubes. When all the tubes are empty the refrigeration cycle starts over again.

18-20. MILK COOLER

A very important application of refrigeration is the farm milk cooler.



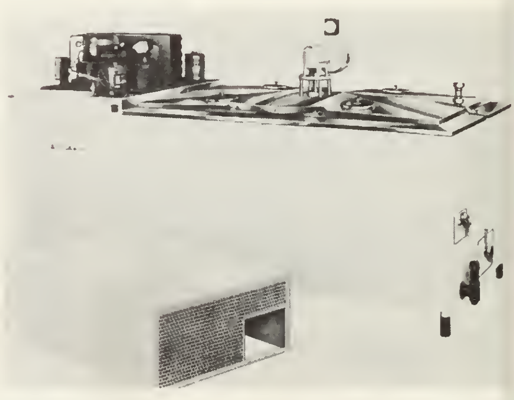
18-37. A phantom view of a milk cooler. Note the water overflow. This water level insures that the cold water is the correct height. The cooling coil is attached to the cabinet liner.
(Esco Cabinet Co.)

It is necessary to cool milk to 50 F. within one hour after the milk has been taken from the cow and it is required that the milk be kept at a 40 F. or lower storage temperature. State laws require this application of refrigeration. The purpose of this refrigeration is to keep the bacteria growth at a very minimum.

The rate that bacteria multiply or increase in milk is dramatically illustrated by noting the rate that bacteria grow at different temperatures. During a 24 hour period, the bacteria will increase to 2,400 at 32 F., to 2,500 at 39 F., to 3,100 at 46 F., to 11,600 at 50 F., to 180,000 at 60 F., and to 1,400,000,000 at 86 F. One can easily see from this data why the milk should be cooled. Milk is commonly kept in 10 gallon cans, standardized as to shape and size. The farmer uses a milk cooler adapted to these cans. Many of the coolers are of the immersion type and the cans are inserted in refrigerated water, Fig. 18-36. This water is circulated by a small motor-driven water pump. Some units spray the water over the cans to achieve quicker heat removal. Other units rock the cans to stir the milk in the cans and the cooling water outside to produce quicker cooling. Figure 18-37 shows a

18-38. A front-opening milk cooler.
(Wilson Refrigeration, Inc.)

constant water level device which insures cold water of the proper level regardless of the number of cans in the cooler.



18-39. A bulk type milk cooler. Note the refrigerating condensing unit and the pump.
(Wilson Refrigeration, Inc.)

Because the milk laden cans are heavy (nearly 100 pounds) some milk coolers have side doors and cold water is sprayed or flowed over the milk cans. These cabinets must have water tight doors and a means to pump the water over the cans and store it while the cabinet is opened to remove the milk cans, Fig. 18-38.

Cooling milk in bulk is increasing in popularity. Figure 18-39 shows a bulk milk cooler. The tank is stainless steel. The agitator and shaft are also made of stainless steel.

18-21. BAKERIES

Bakeries are using more refrigeration to help them improve products. Many of their raw products must be kept at refrigerated temperatures. Frozen ingredients must also be stored. Even the water and flour used for bread making must be cooled during certain periods of the year. Creams and custards are better kept in a cool temperature.

Some examples of refrigeration in baking are as follows:

Flour storage	70 F	60% humidity
Butter, liquid milk yeast, syrups, eggs fruits, fillings	40 F	
Frozen eggs and fruits	0 F	
Custards, whipped cream foods	40 F	
Mixing water	34 F	
Yeast raised dough retarding	35 F	

Air conditioning is extensively used in bakeries as the humidity is also very important in many baking processes. If bread is fast frozen to -10 F. it will remain fresh for almost a month.

18-22. FUR STORAGE

It has been found that if furs are passed through a low temperature storage period, the moth, whether it is in the moth stage, egg stage or larvae stage will be destroyed. Common practice is to first cool the furs to 15 F. to 20 F. then allow the furs to warm up to above 50 F. for 24 to 48 hours. After this cycle, which is found to be the most effective, the furs are stored at 35 F. to 40 F.

The refrigerator is usually constructed like a cold storage room, with concrete walls, thoroughly moisture sealed with asphalt, corkboard insulation or its equivalent, and a double door. The inside door is a regular refrigerator door while the outside door is a vault door.

Blower cooling coils are used to force air circulation around and into the furs. The humidity must be kept up to 55% to prevent drying the skin of the furs.

It is imperative that these storage vaults be of fireproof construction.

18-23. INDUSTRIAL APPLICATIONS

Refrigeration is being used extensively to aid manufacturing processes. The units are of great variety but the smaller units are automatic in operation. Two very common applications are cooling of water which in turn cools electrodes on resistance welders and the cooling of quenching liquids for super cooling of metals for heat treating.

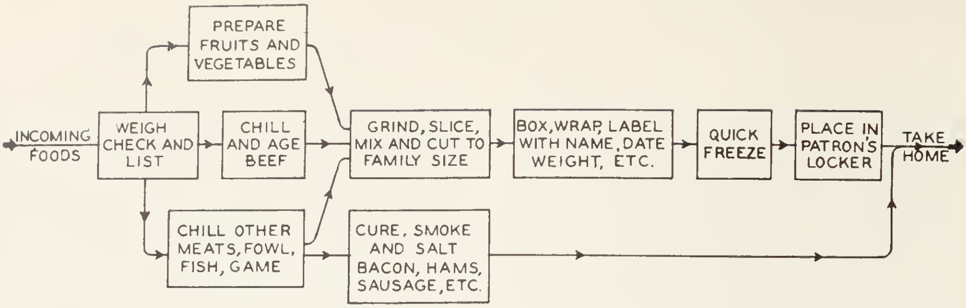
18-24. INDUSTRIAL FREEZING OF FOODS

Industrial freezing of food is carried on in two types of establishments:

a. Processing Plants

b. Locker Plants

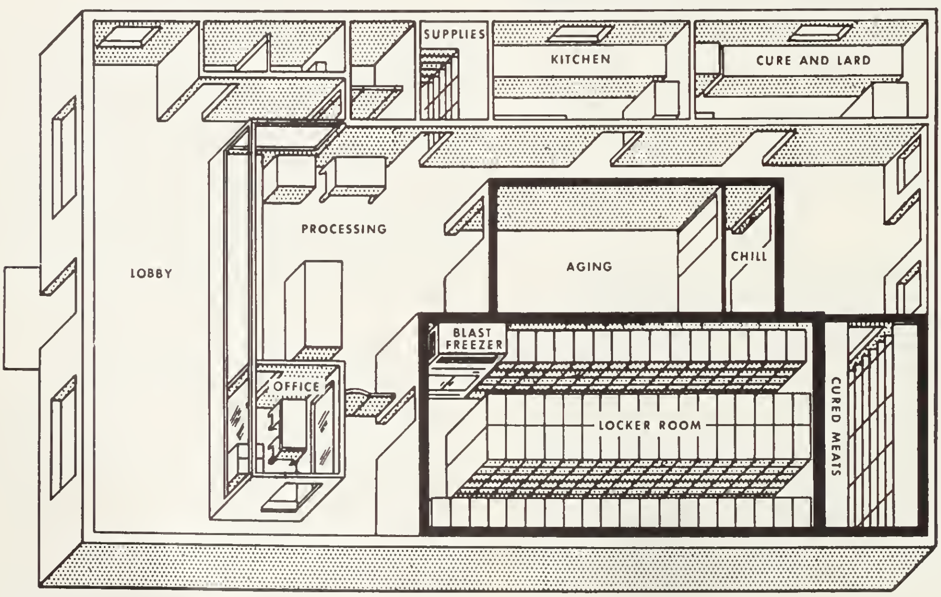
The factory processing type is found in central producing sections such as near canneries. Processors of popular brands of frozen foods have freezing centers located in many large produc-



18-40. Food flow through a freezing plant.
(American Society of Refrigerating Engineers)

ing areas in the United States. An example of this type of processing is the processing of fish which are packed and frozen along the coast and then shipped to all parts of the country.

The locker plant is a smaller unit and operated locally, preparing, freezing and storing products for producers and for sale to other customers. The types of refrigerating equipment in both plants may vary some, but the plan of freezing the food is similar. Figure 18-40 shows the flow of produce through a plant. The food is weighed and checked for purity and suitability for freezing. It is important to remember that low quality food cannot be made first quality by fast freezing. Then it moves to the processing room. In the processing room the meats are cut, fowl are cleaned and dressed, vegetables blanched and all types of meats, fruits and vegetables are packaged. Next, the foods are sent to the freezing section where they are completely frozen and made ready for storage, Fig. 18-41. An ultra violet ray lamp is usually placed in the aging room to kill bacteria, Fig. 18-9. All processing plants attempt to freeze the food as fast as



18-41. A typical locker plant. A special blast freezer is used to fast freeze the food before it is stored in the locker room.
(Frigidaire Div., General Motors Corp.)

18-42. A polar chest freezer rack.
(American Society of Refrigerating Engineers)

possible. They also attempt to contact as much of the food as possible with as low a temperature as possible. Some foods are immersed in sub-zero liquids, some are pressed between low temperature plates, some are exposed to blasts of low temperature air and some are sprayed with a cooling liquid.

18-25. INDUSTRIAL STORAGE OF FROZEN FOODS

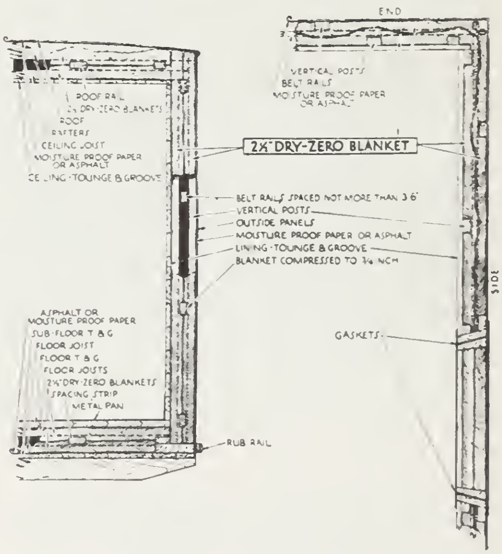
The storage requirements of all foods are about the same with a temperature of 0 F. to -20 F. desirable and a variation of 2 to 3 F. allowed normally. An excessive temperature differential produces "breathing" and volume changes that are detrimental. The humidity in the storage rooms should be as high as possible. High humidity is accomplished by the design of the equipment in the commercial freezing plant or by the design of the locker plant as the conditions are identical. Cooling of the storage area may be accomplished by blower coils, direct contact plates or brine coils.

In the smaller plants the customer enters the refrigerated area and pulls out a drawer containing the food. In some locker plants special construction makes it possible to deliver frozen foods from the storage area to the customer without entering the cold area. One of these installations is called the "Polar Chest," which has the lockers below the floor, Fig. 18-42. When food is needed the locker is raised up through the floor into a room of normal temperature.

18-26. TRUCK REFRIGERATION

Truck refrigeration requires specially designed truck bodies and specially designed refrigeration units.

The bodies must be light, well insulated and withstand hard usage. The

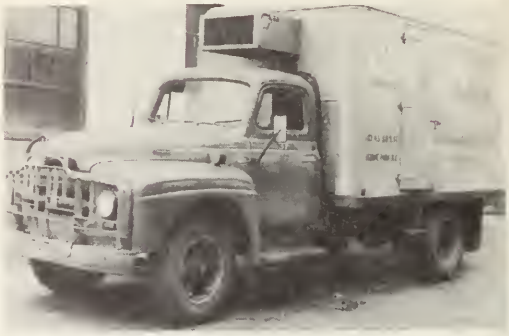


18-43. A refrigerated truck body.
(Dry Zero Corp.)

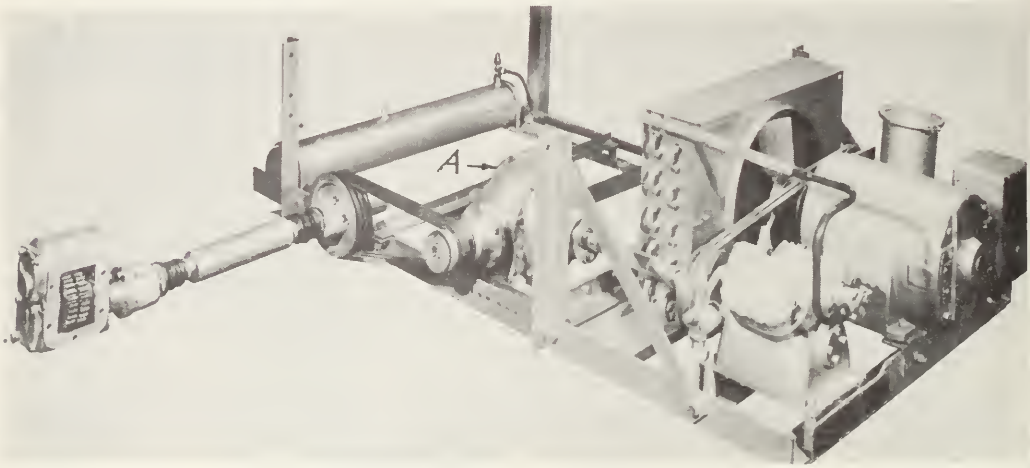
construction, of course, must be light but sturdy so that continual vibration and rough handling will not destroy the insulating value of the walls. Various insulating materials have been used. Figure 18-43. One insulation that has great possibilities is the metal foil

type explained in Chapter 9. The most interesting things about truck refrigeration are the styles and mechanisms used. Because of the many uses of truck refrigeration, the desired temperatures naturally vary, therefore each problem must be studied before a temperature may be recommended. Dry-ice trucks must be insulated for -109 F.; ice cream trucks for 0 F. to 5 F., while other commodities often use 35 F. to 40 F. temperatures. These trucks have many variations in application, but the systems used to produce refrigeration may be divided into three main types:

1. Ice
2. Dry ice
3. Mechanical



18-45. A refrigerated truck that used a dual refrigerating system.
(Lehigh Mfg. Co.)



18-44. A truck refrigeration condensing unit. It has a transmission power take off for use on the road and a standard electric motor for overnight parking and cool down. A hydraulic clutch (A) operated by a solenoid valve engages and disengages the compressor from the power sources automatically.
(Kold Hold Div., Tranter Mfg. Inc.)

The ice method is used, but because of weight and loading is decreasing in popularity. The use of dry ice is increasing because of the weight reduction, and the drainage problem is eliminated. However, some difficulty is encountered in controlling the temperatures.

Mechanical refrigeration comprises the typical refrigerating unit in most cases, the major variation being in the nature of the compressor drive. These drives are:

1. Engine driven electric generator and motor.
2. Driven off the transmission shaft.
3. Separate gasoline engine.

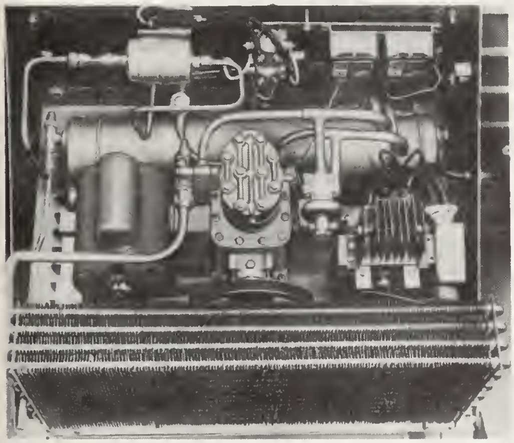
The generator and motor use voltages, cycle, and phases which enable

plugging the motor into a wall plug in the garage if it is desired to keep the truck cold over night.

The transmission power take-off is shown in Fig. 18-44. It uses a standard motor when the truck is parked and with engine shut off (overnight parking).

The gasoline engine driven units are automatically controlled to start and stop as the system requires.

Some trucks use a dual refrigeration system. Figure 18-45 shows a refrigerated truck with a refrigerating unit mounted on the truck body over the cab. This unit is only the standby unit and is used only when the truck is parked for any length of time. Figure 18-46 shows the inside of this unit. In addition to this condensing unit, there is a compressor mounted on the truck engine and driven by the engine, Figure 18-47.



18-46. The standby truck refrigerating unit. Note the sight glass and the dehydrator. (Lehigh Mfg. Co.)

A diagram of the complete installation is given in Fig. 18-48.

18-27. RAILWAY CAR REFRIGERATION

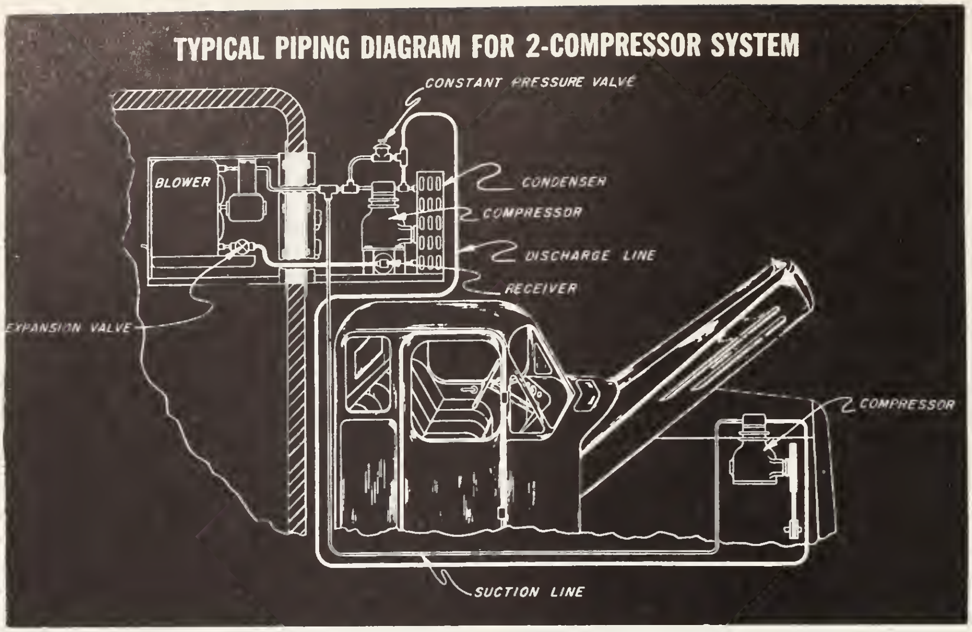
Refrigerator cars have long been used as a means of transporting perishable goods. However, these cars used ice and sometimes salt and ice mixtures as the refrigerating medium. Recently, however, to obtain colder temperatures and to permit faster loading of the cars, mechanical refrigeration has entered this field. As far as the cars themselves are concerned, the construction is very similar to that of the ice car construction, except that the builders are continually seeking to reduce the weight.

In order to attack any commercial refrigeration problem correctly, one must first determine all of the requirements concerning the job to be done; next specify, install, and adjust the mechanism to obtain the correct operation. Basically the requirements are to maintain certain temperatures and frequently certain humidities in storage spaces. How it is done is not so important as that it is done economically and consistently.

18-47. The truck engine driven refrigeration compressor. (Lehigh Mfg. Co.)

Refer to Chapter 21 for methods of calculating heat loads.

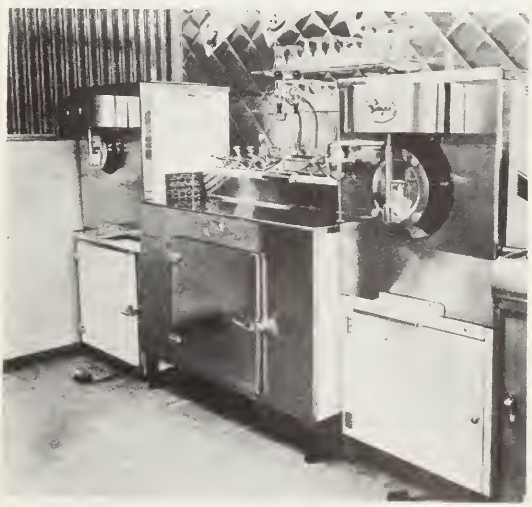
Two different types of refrigeration systems are used on trains. These are freight refrigeration and air-conditioning in passenger cars.



18-48. A truck refrigerating system which uses an engine driven compressor and a stand-by motor driven compressor.
(Lehigh Mfg. Co.)

Freight refrigeration may be by means of water ice, dry ice, or mechanical refrigeration. The present trend is toward mechanical refrigeration. Passenger car air-conditioning is by mechanical refrigeration.

The compressors, in mechanical installations, are usually driven from the car axle while the cars are in motion and by an electric motor while the cars are in the yard.



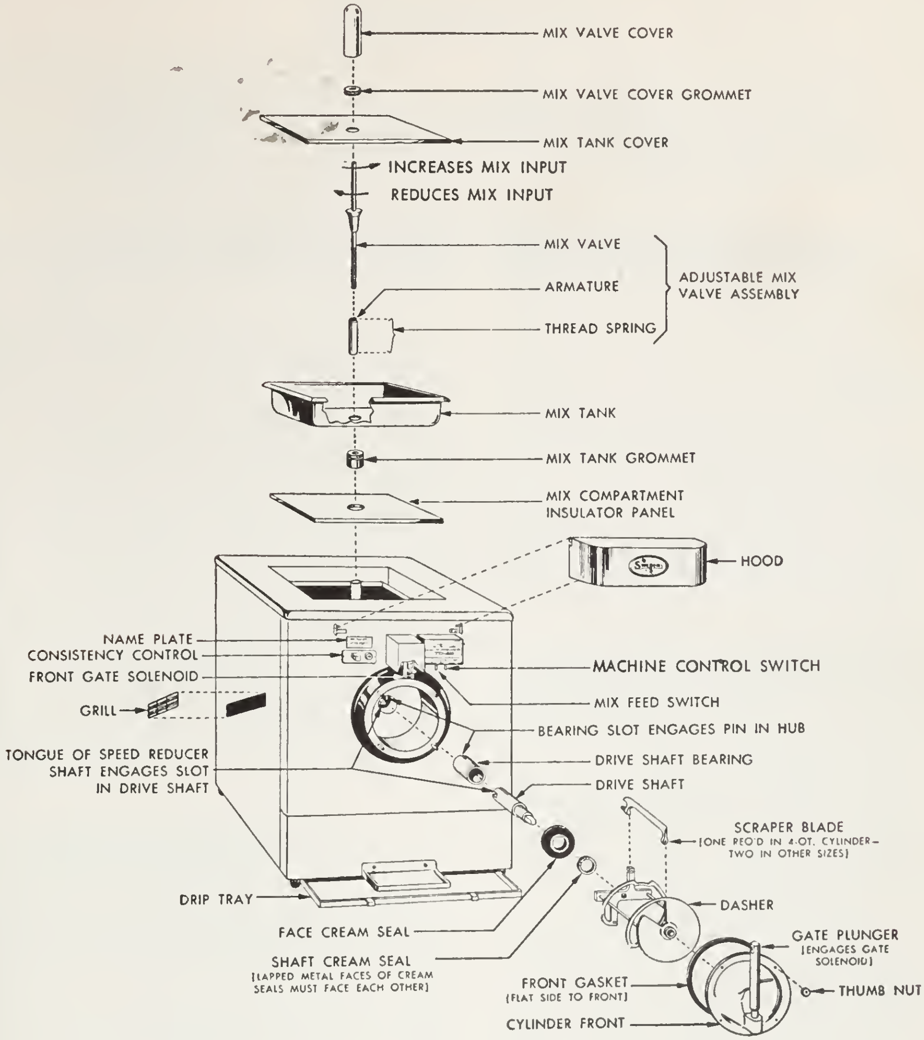
18-49. A fast freezer for malteds, sherbets and custards. Two freezers are shown with a soda fountain installed between them.
(Sweden Freezer Mfg. Co.)

Some train refrigeration systems have been developed using the absorption system. Others have employed the steam jet system of refrigeration.

Marine Refrigeration is basically the same as land-type equipment. However, the refrigerants used are restricted to ones which are non-toxic and non-flammable. All cases are very carefully sealed in to exclude the possibility of moisture entering the insulation. Refrigerant lines must be installed to permit some vibration without danger of becoming broken.

18-28. ICE CREAM MAKERS

A special application of refrigerating systems is the frozen custard or ice cream making machines. These units use a large refrigerating machine to fast freeze the mix. The same or another motor is used to drive the stirring mechanism (dasher). A 1/2 H.P. refrigerating unit can fast freeze one gallon (32 two-ounce servings) of



18-50. An exploded view of an automatic fast freezer. Note the dasher, the gate plunger and the dasher drive shaft.
(Sweden Freezer Mfg. Co.)

custard in about six minutes, Fig. 18-49.

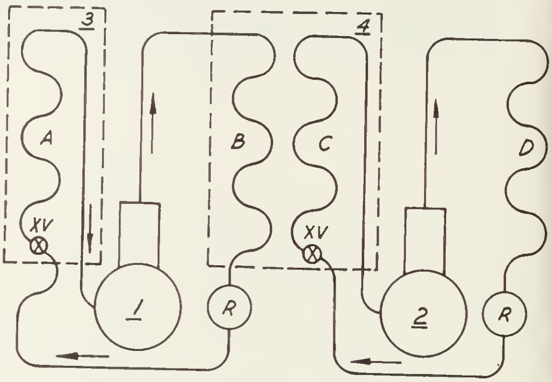
Some units are continuous in operation. Thermostat expansion valves are usually used as the refrigerant control. The machine is usually adjusted to deliver the custard or sherbets at 20 F. A total of 3 H.P. can operate the refrigerating unit and drive the dasher for a 12.5 gallons per hour capacity unit. A 25 gallon per hour capacity unit usually uses a 2 H.P. dasher motor and a 3 H.P. refrigerating unit. The larger units are water cooled.

A mix storage or supply cabinet is usually used with three units to store the mix until it is used.

Figure 18-50 shows an exploded view of a cabinet and the controls. The units must be kept as clean as possible.

18-29. REVIEW QUESTIONS

1. What cabinet temperatures are recommended for the following commercial installations, water-cooling, walk-in coolers, florist's cabinet, and ice cream cabinet?
2. Why is it necessary that the doors and windows in these cabinets be air-tight?
3. What is the purpose of dead air spaces formed between the two and three pane windows in these cabinets?
4. How is moisture kept out from between multiple pane windows?
5. Why are the lights of the display counters usually located outside of the counter?
6. If one were to mount a thermometer in one of the walk-in cabinets, where would one find the average temperature?
7. Why are most commercial refrigeration installations of the multiple type?
8. To what temperature would you permit water to be cooled, (a) if the bubbler was located in the heat treating room of a tool and die factory? (b) in an office building?
9. Why does the length of the counter affect the number of end bunkers in an end bunker display cabinet?
10. Why must the humidity be kept very high in produce storage cabinets?
11. How is the cold air kept from spilling from the open display cases?
12. What is a double duty display case?
13. Where are the cooling coils located in open display cases?
14. How are frozen food open display case coils defrosted?
15. What are the two basic types of ice cube makers?
16. What is hot gas defrosting?
17. Why does the typical milk can cooler have a water pump?
18. Why must milk be cooled shortly after it has been taken from the cow?



18-51. A cascade refrigerating system. The condenser (B) of system 1 is being cooled by the cooling coil (C) of system 2. This arrangement enables the production of very low (ultra-low) temperatures in the cabinet 3. A Ultra low cooling coil, D condenser of system 2, XY refrigerant controls, R liquid receivers, 4 heat exchanger.

18-30. CASCADE SYSTEMS

One of the means used to obtain ultra-low temperatures is to place two or more refrigerating systems in series (cascade system). This method uses the cooling coil of one machine to cool the condenser of the other machine. See Fig. 18-51. Usually two different refrigerants are used, each being adapted to the temperature-pressure conditions under which it operates. For example, system 1 could use Refrigerant 13 (Freon 13) while system 2 could use Refrigerant 22 (Freon 22).

Chapter 19

COMMERCIAL REFRIGERATION SYSTEMS AND MECHANISMS

The refrigerating machines used to refrigerate the multitude of commercial refrigeration applications vary considerably in size and in appearance. Small machines (1/8 H.P) are used for beverage coolers, dehumidifiers, etc. Up to 7 1/2 and 15 H.P. machines are used for frozen food walk-in cabinets, industrial cooling, etc., Fig. 19-1.

It is difficult to cover all of these mechanisms and in this chapter an attempt is made to explain the design, construction and operation of the most popular units.

19-1. CONSTRUCTION OF REFRIGERATING MECHANISM

The same fundamental types of cycles are used in commercial refrigeration that are used in the field of domestic refrigeration. These are the mechanical cycle and the absorption cycle.

The absorption cycle is treated in this particular part of the text, but is discussed in Chapter 14. The construction and operation of them is very similar to the ones studied in Chapter 14. These absorption machines are used for water-cooling, ice cream cabinets, and other smaller commercial applications.

The mechanical cycle and mechanism vary from that of the domestic cycle mainly in the multiplicity of cooling units connected to one condensing unit and the special designs required for larger units.

The following discusses details of construction of the various mechanical commercial refrigerating machines:

19-2. THE MECHANICAL CYCLE

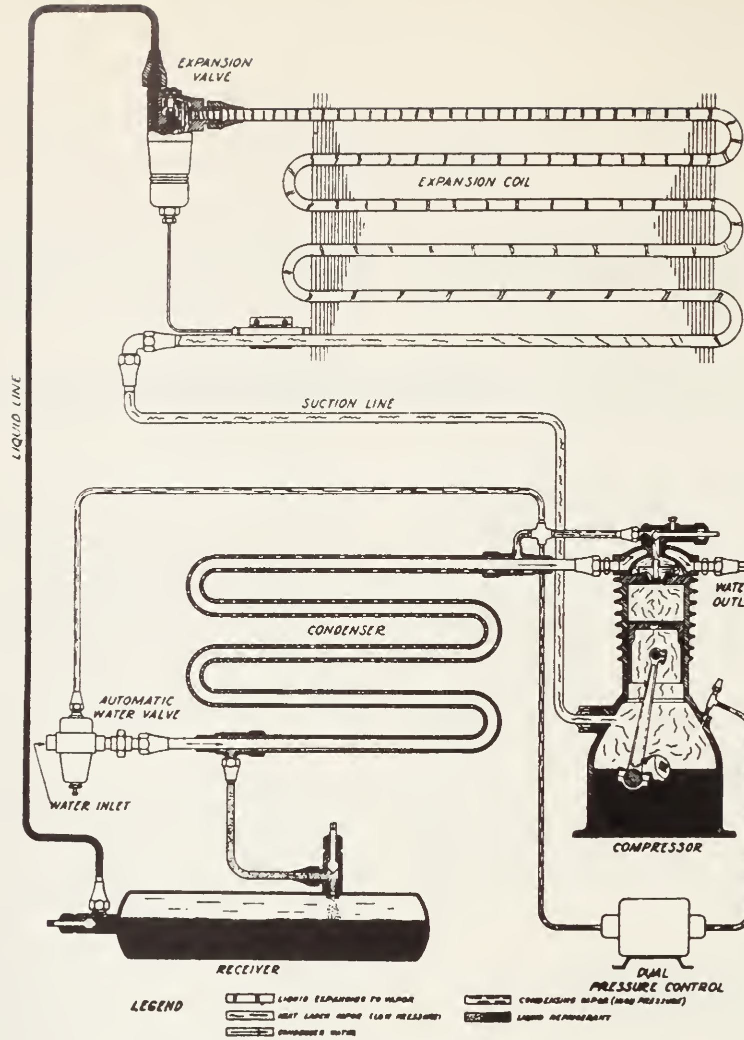
Most of the commercial refrigerating apparatus is of conventional design (completely serviceable), but many of the single applications such as bottle coolers, beverage dispensers, and ice cream cabinets are constructed in the hermetic style, using apparatus very similar to the designs shown in Chapter 10, except that the cabinet varies according to the application.

The conventional refrigerating machine is composed fundamentally of parts very similar to those of the domestic machine. The unit is constructed to vaporize a refrigerant under a controlled pressure in a cooling coil. The gas formed is then passed to the condensing unit which removes the heat from the gas and reconverts it into a liquid, Figure 19-2.

Only two pressures are needed, the vaporizing pressure (low) and the condensing pressure (high). See Chapter 1.

19-3. COMPLETE MECHANICAL MECHANISM

The single unit commercial refrig-



19-1. A typical commercial water-cooled unit showing a tube-within-a-tube condenser and a water cooled compressor head.
(Tecumseh Products)

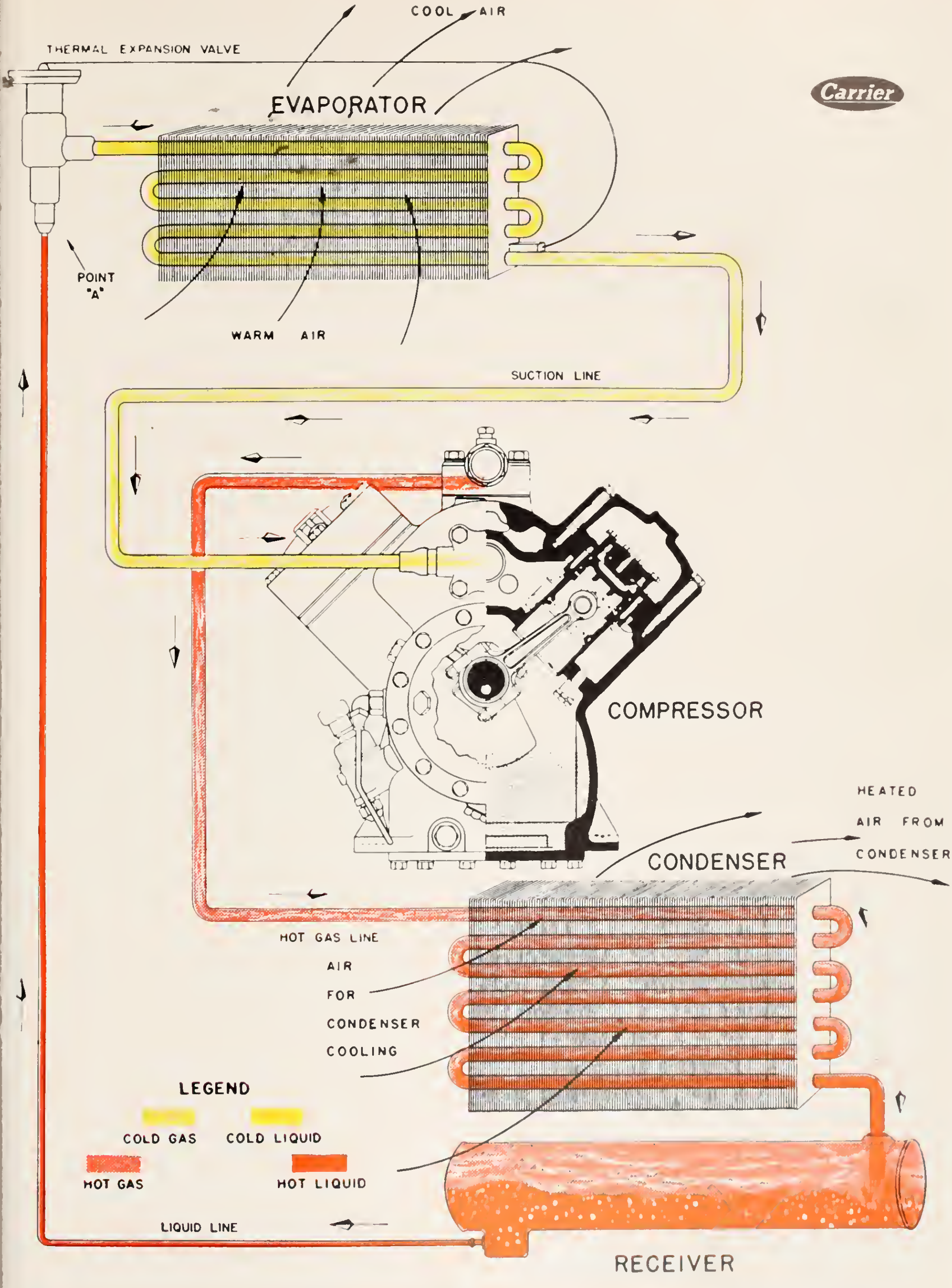
erating mechanism apparatus consists of:

A. The high pressure side, Fig. 19-2:
   1. The compressor
   2. The condenser (usually air-cooled)
   3. The liquid receiver
   4. The high pressure safety motor control
   5. The liquid line

B. The low pressure side:
   1. The refrigerant control (thermostatic expansion valves or lowside floats)
   2. The cooling unit
   3. The low pressure or temperature motor control
   4. The suction line

The multiple mechanical mechanism consists of:

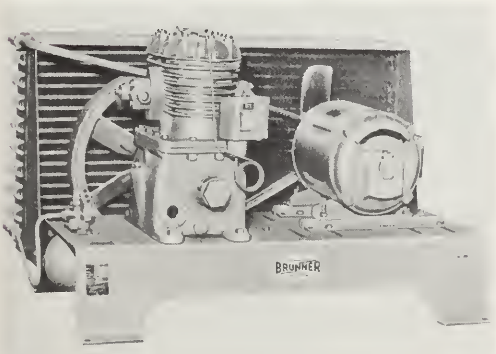
A. The high pressure side
   1. The compressor
   2. The condenser
      a) Water-cooled or air-cooled
   3. The liquid receiver (with an air-cooled condenser or with a tube within a tube condenser)
   4. The high pressure motor control (safety)



19-2. A typical commercial system cycle using an air cooled condenser, a thermostatic expansion valve, and a V-type compressor.
(Carrier Corp.)

5. The liquid lines (with a distributing manifold)
6. A water valve (used with a water-cooled unit)

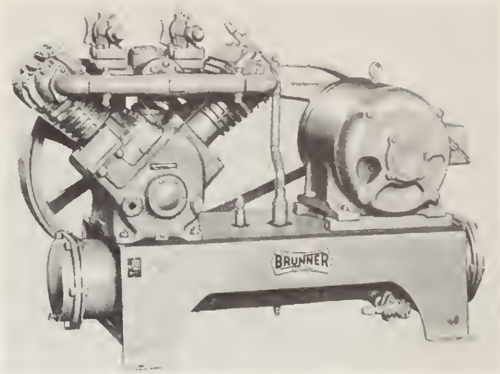
B. The low pressure side
1. The refrigerant controls (two or more which may be either of the low side float or the thermostatic expansion valve construction)
2. The cooling units (two or more which may be of the natural convection, forced convection, or submerged types)
3. The motor control (which is usually of the pressure type)
4. The suction lines with a suction line manifold.
5. Two-temperature valves (for multiple temperature installations)



19-3. An air-cooled conventional commercial condensing unit. It has a three pass air cooled condenser, a two cylinder vertical compressor, a three belt drive, a high pressure safety cut-out, and a glass oil level indicator. (Brunner Mfg. Co.)

6. Surge tanks (for absorbing pressure fluctuations)
7. Check valves (for multiple temperature installations)

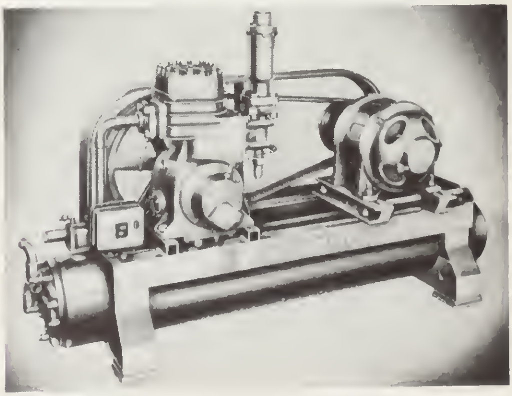
The condensing units are mounted on steel or cast iron bases, the motors are connected to the compressor by one, two, or three belt drives. A large two-stage condensing unit is shown in Fig. 19-4. It is a 25 H.P. unit and has two 2 1/8 in. solder-type suction line



19-4. A water cooled commercial condensing unit, which has a four cylinder, V-type compressor a shell and tube water cooled condenser, flange type suction line connections. This unit is a two-stage compressor with three cylinders pumping gas into one high pressure cylinder (far right cylinder). (Brunner Mfg. Co.)

connections and one 1 3/8 in. solder-type liquid line. It is designed for low temperature work and has a 40,600 Btu/hr. capacity at -52 F..

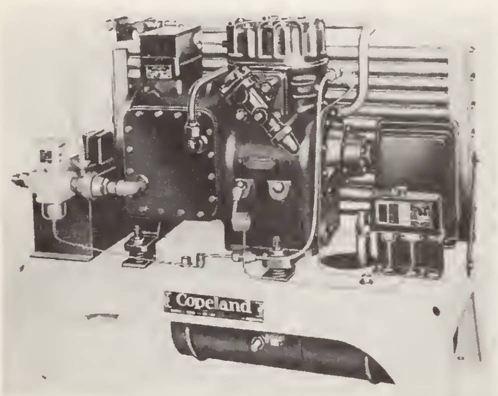
A fabricated steel frame is used to hold the shell and tube condenser of the S.H.P. unit shown in Fig. 19-5. Note the universal electric motor mount. The suction line connects to the right side of the compressor. The piping is fastened to the compressor by four bolt flanges.



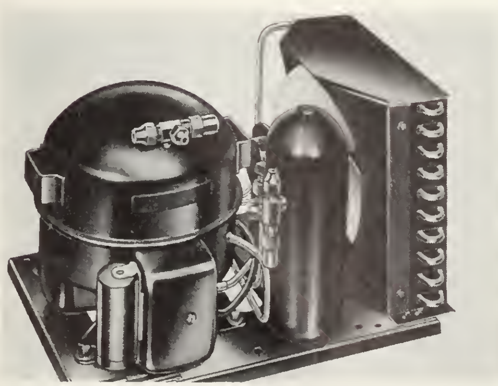
19-5. A five horsepower water cooled commercial condensing unit. (Frigidaire Div. General Motors Corp.)

19-4. COMMERCIAL HERMETIC UNITS

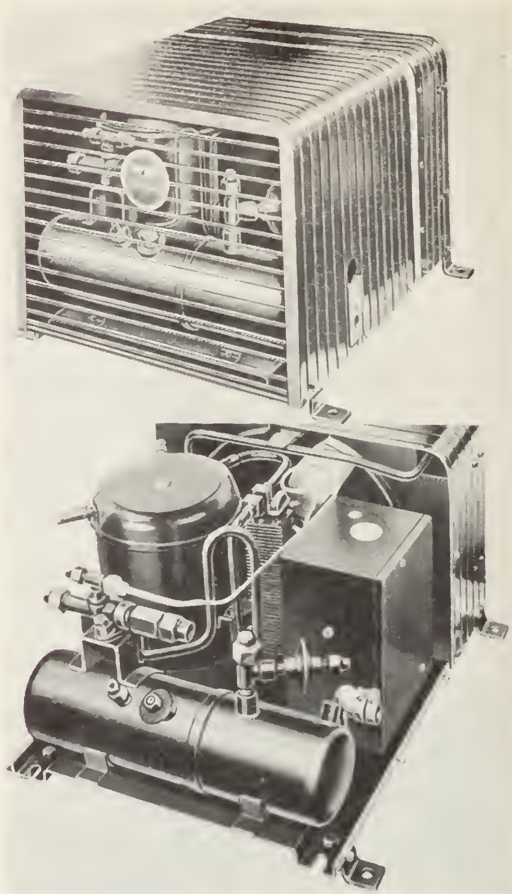
Many companies are now producing larger hermetic units. Some companies have produced commercial hermetic units for years. Several companies are now producing units up to 7 H.P. and they are proving to be very satisfactory. Some of these units are of the bolted assembly type. Some units are welded or soldered together. However,



19-6. A commercial hermetic condensing unit.
(Copeland Refrigeration Corp.)



19-7. A 1/4 H.P. commercial hermetic condensing unit. An air cooled condenser is used and a separate motor is used to drive the condenser fan.
(Tecumseh Products Co.)



19-8. A commercial motor-compressor unit with service valves.
(Frigidaire Div., General Motors Corp.)

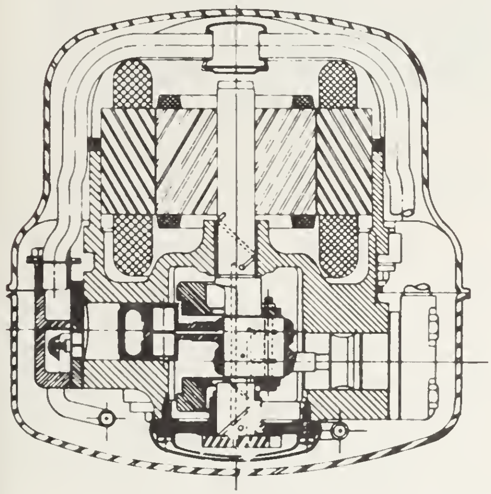
they are all equipped with service valves and may be connected to any type of condenser or cooling coil desired.

The chief advantage in the use of hermetics in the commercial field is the elimination of the crankshaft seal and belts, Fig. 19-6.

Because any trouble in the compressor mechanism involves both the compressor and the motor, it is essential that the service man be extra cautious that moisture and dirt do not enter these systems.

A 1/4 H.P. commercial hermetic condensing unit is shown in Fig. 19-7. Note the suction service valve on the compressor dome, the liquid receiver

service valve on the receiver, and the forced convection condenser. A motor-compressor equipped with a fan condenser, a shroud, and service valves is shown in Fig. 19-8. The internal design of a motor-compressor is shown in Fig. 19-9. The motors are single phase in the smaller units but three phase motors are used in the units over 1/2 H.P., Fig. 19-10.



19-9. A cross-sectional view of a hermetic motor-compressor as used on commercial condensing units.

(Tecumseh Products Co.)

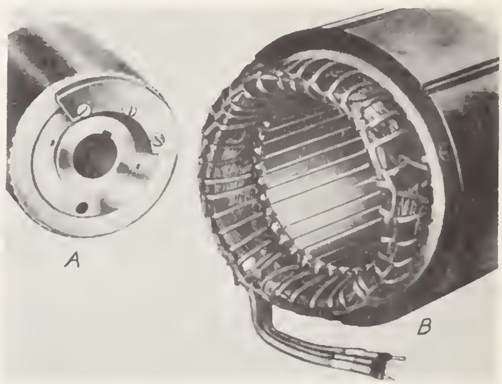
19-5. THE COMPRESSOR

The typical conventional commercial compressor is of vertical reciprocating construction, made of one or more cast-steel nickel-alloy cylinders which use cast-iron pistons, driven by means of a drop forged connecting rod and a hardened steel, full-floating piston pin.

The connecting rod is attached to a crank throw type or eccentric type of crankshaft which is drop forged and case hardened. The bearings are typically bronze alloy. Main bearings are made of a similar material although some companies use the crankcase material for main bearings.

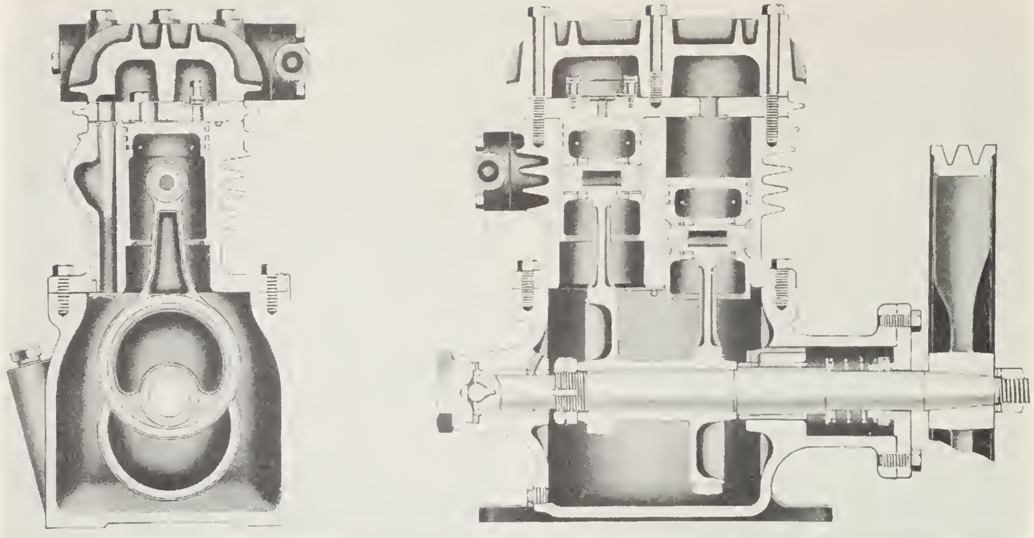
The crankshaft seal may be of the type wherein the bellows is stationary and presses against a crankshaft shoulder, or may be of the type where the bellows is sealed to the crankshaft and revolves with it. The oiling of the compressor is done by the splash system or by a force-feed lubrication to all moving parts.

The compressors usually have a double cylinder head. The intermediate one carries the exhaust valves. The cylinder heads are made of the same material as the cylinder body, although some companies make the intermediate one of steel plate, Fig. 19-11. The intake valves and the exhaust valves are made of very thin spring steel, similar to those used in the domestic models. The design, however, changes with the size of the unit. Large compressors use multiple disks and port openings instead of the single opening employed in domestic units. The intake valve is usually located in a plate between the cylinder head and the cylinder, but the design varies with practically every manufacturer.



19-10. A three-phase electric motor as used in larger hermetic refrigeration units. A. Rotor; B. Stator.
(The Emerson Electric Mfg. Co.)

Almost without exception the pistons are equipped with two or more rings. The clearances permitted for all moving parts are a little more than



19-11. A cross section view of a two cylinder commercial compressor. Note the valve plate and the rotary seal. (Brunner Mfg. Co.)

those allowed in the domestic mechanisms, but they are one thousandth of an inch (.001) or less. The cylinder heads of these compressors must be cooled; radiating fins are therefore constructed into the cylinder head and cylinder body in the smaller sizes. Refrigerant-cooled and water-cooled heads are the rule in the larger models. The speed of these compressors is kept to a minimum. Since the belief is that slow speed enables a longer-lived and a more efficient compressor, the usual speed varies between 300 and 500 r.p.m. The means for driving these compressors is almost universally the V-type belt in multiple. One finds two to ten belts quite common as the power transmitting medium.

The service valves in the smaller units are exactly the same as those described for the domestic conventional designs. In one-ton machines and larger, especially those using stream-line fittings, a different standard has been developed. On the larger mediums the valves are still of the two-way type, but instead of the typical two-bolt flange, these valves are often attached by means of four bolts and are gasketed with recessed lead gaskets.

The very largest units have these valves furnished with hand wheels, whereas the others use a 3/8-in. square steel stem. Many companies are now producing compressors with oil level sight gauges, because of the importance to the life of the compressor in having the oil level correct.

19-6. AIR COOLED CONDENSER

Air-cooled condensers are quite common in the smaller units, or where cooling water is not available. These are cooled by a large fan located on the motor or built into the compressor flywheel on the conventional units. Hermetic units use special motors to drive the fan.

The efficiency of the air-cooled condenser may be increased by the use of a metal shroud around it and the use of a cooling fan. Air can be drawn through the condenser or driven through it. These condensers have dip soldered fins and a double or triple layer of tubes is frequently used.

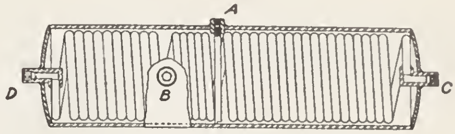
In order to cool the compressor

head and valves, a double air-cooled condenser is used by one of the companies. This condenser is so arranged that the refrigerant, when leaving the compressor, passes through one condenser and is then led back through jackets surrounding the cylinder head. From there it goes into the second condenser where it is finally cooled and condensed into a liquid. The partially cooled refrigerant, as it passes through the compressor head, keeps the compressor head cool.

See Chapter 8 for determining condensing temperatures and pressures when an air-cooled condenser is used. In many communities, water cooling has been drastically curtailed or prohibited for refrigerating systems and air conditioning systems.

Air cooled condensers have been developed that enable large units to operate quite efficiently. These units can be mounted outdoors or indoors using ducts. The units use a minimum of accessories and are virtually maintenance free, Fig. 19-12. The unit is mounted on a platform for better air circulation and the fan and motor have a protective hood mounted over them.

19-12. A commercial system remote air cooled condenser designed for mounting outdoors or in a duct system.
(Peerless of America)



19-13. A water-cooled condenser which also serves as the liquid receiver. A. Refrigerant out; B. Refrigerant in; C. Water in; D. Water out.
(Williams Oil-O-Matic Heating Corp.)

19-7. WATER COOLED CONDENSER

The most common of the condensers used for cooling commercial refrigerating apparatus is the water-cooled type. This condenser is built in two different styles.

One style is constructed so the refrigerant goes directly from the compressor into the interior of a tank or shell.

The other type uses two pipes or tubes one within the other. The refrigerant passes one way through the outer pipe, while the condenser water passes the other way through the inner tube.

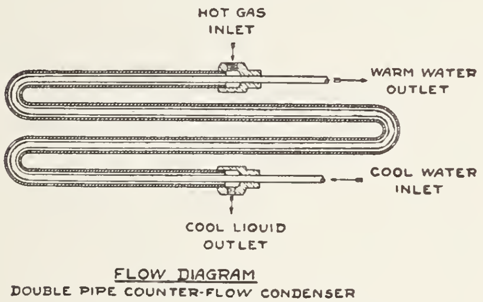
19-8. SHELL TYPE CONDENSER

The shell type condenser or shell and tube type as it is commonly called, is a tank made of steel with copper tubes inserted in the shell. Water circulates through the tubing and condenses hot gases into a liquid. The bottom of the shell serves as the liquid receiver, Figure 19-13. The advantages of this style of construction are compactness of design, the elimination of fans and a separate condenser. Also, it enables a very flexible type of assembly. Some companies produced this type of condenser with the exception that instead of a coil of copper tubing being used as the water passages, the liquid receiver was made

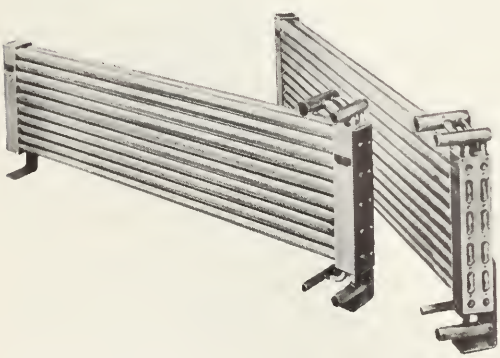
with a double wall; the cooling water circulated between the double walls of the liquid receiver.

19-9. TUBE-WITHIN-A-TUBE CONDENSER

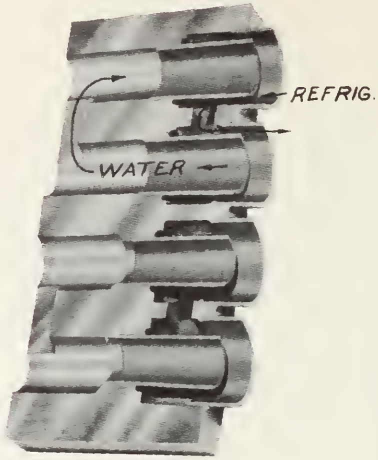
The other type of water-cooled condenser, which is becoming very popular because it can easily be made to fit the size of the unit to be cooled, is the double tube type. One tube is put within another in such a way that water passing through the inside tube cools the refrigerant in the outside tubing, Fig. 19-14. The outside tubing is also cooled by the air in the room, enabling very efficient operation. This condenser may be constructed either in the cylindrical spiral style or in the rectangular style, Fig. 19-15.



19-14. A tube-within-a-tube water-cooled condenser. (General Refrigeration Sales Corp.)



19-15. A tube-within-a-tube condenser designed to permit cleaning the water tubes (inner). The clean out plate is removed in the right hand view. (Halstead and Mitchell)



19-16. Detail of the construction of a tube-within-a-tube condenser. Note how both the refrigerant tubes and the water tubes are silver brazed into the header. (Halstead and Mitchell)

The water enters the condenser at the point where the refrigerant leaves the condenser to go into the liquid receiver, and the water leaves the condenser at the point where the compressor is connected to it. This is called the contra-flow construction. The warmest water is adjacent to the warmest refrigerant, and the coolest water adjacent to the coolest refrigerant, Fig. 19-15.

Water-cooled compressors are sometimes used with water-cooled condensers. The water flow, with few exceptions, is through the condenser first, then through the cylinder head, and finally out into the drain. The water flow through these condensers is regulated by means of an automatic water valve, Paragraph 19-49.

19-10. COMBINATION CONDENSERS

To economize on the consumption of water, some commercial units have both air-cooled and water condensers. These condensers are connected together. Under ordinary conditions only the air-cooled condenser is used. How-

ever, if the unit is pumping considerable gas, or if the air temperature rises too much, the head pressure of the unit will rise enough to force a water valve open. The condenser then starts to cool with both air and water, Fig. 19-17.

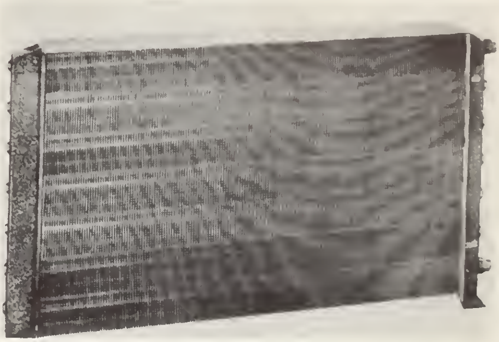
19-11. COOLING TOWERS

In some localities the water contains chemicals (hard water), or water may be very scarce, expensive, and its use may be limited by law.

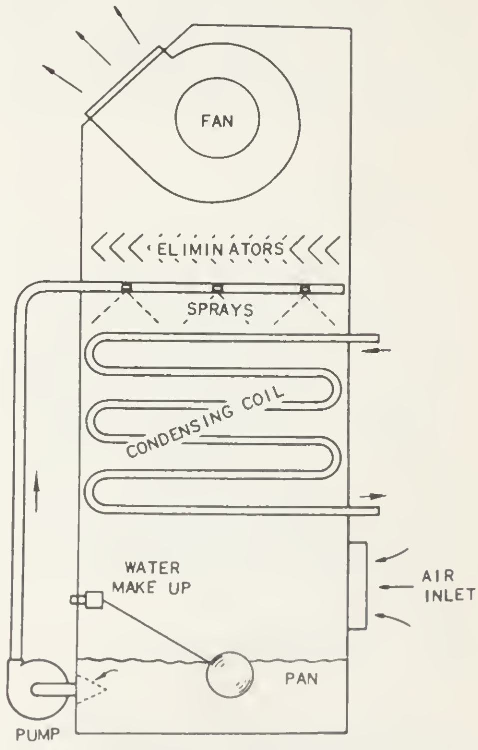
To enable a user to have a water cooled mechanism and yet save considerably on water consumption, water cooling towers have been built. These cooling towers cool adequately and use only about 15 per cent as much water as a direct water flow to the drain would consume. These cooling towers are small copies of the spray towers used in large industrial refrigeration systems.

One system connects the water lines of the condenser to a water coil in an enclosure. A pump forces the water through the coil in the tower. The coil is pierced with holes and the water is sprayed into the enclosure. A motor driven fan forces air through the enclosure. The air rushing through the sprayed water, evaporates some of it and the evaporation cools the remaining water to the outdoor temperature or even lower. The cooled water collects in the bottom of the enclosure and is picked up through a screen and recirculated through the condenser. Chemicals may be put in the water to retard rust formation, fungus growth, etc.

Another method is to have an indoor storage tank for the water cooled by the cooling tower. A water pump removes the water from the storage tank, forces it through the condenser and then up to the cooling tower. After the water has been evaporative cooled in the cooling tower it drains to the storage tank. The storage tank has a float controlled refill or make-up valve to replace the evaporated water with city water or well water. This float operates similarly to a refrigerant low-side float mechanism. The cooling



19-17. A combination air and water cooled condenser. (Bush Mfg. Co.)



19-18. An evaporative condenser. (Baltimore Air Coil Co., Inc.)

tower fan motor operates only when the storage tank water temperature rises above a temperature set by a thermostat bulb located in the storage tank water.

The cooling towers are made as corrosion proof as possible. The structures are zinc dipped (galvanized) after assembly, they are made of copper, of stainless steel, and of rot-proof wood.

Both the cooling tower and the storage tank have overflow pipes, that carry any excess water to the drain system of the building.

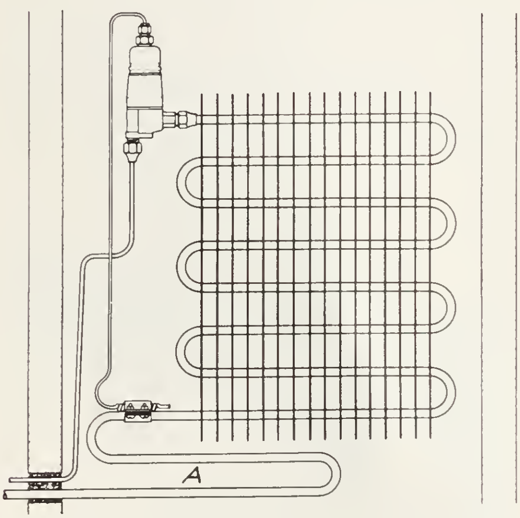
See Chapter 21 for details of sizes and capacities.

19-12. EVAPORATIVE CONDENSERS

Another system carries the refrigerant into a condenser located in an enclosure similar to the cooling tower. In this device water is sprayed over the condenser to cool it. The water cycle is all in the condenser cabinet in this system. Longer refrigerant runs are usually needed to carry refrigerant to the evaporative condensers, Figure 19-18. The air action and the refrigerant action in an evaporative condenser are in Chapter 29.

Usually the evaporative condenser is mounted out of doors; however, it is possible to locate an evaporative condenser indoors by providing air ducts to and from the condenser to the outside.

Some systems pump the water to a tray located above the condenser and the water drips over the coils as air is forced through the coils. A thermostat can be used to control the water flow. A fan operates to blow air over the condenser at all times when the condensing unit is operating. The water is turned on by the thermostat only when the condenser temperature exceeds a certain level (100 F. or more).



19-19 The use of a "dryer" coil (A) to prevent a sweating or frosting suction line outside the fixture. This type coil is usually of the defrosting type. (Detroit Controls Corp.)

19-13. LIQUID RECEIVER

The liquid receiver is a steel tank of welded construction and is usually equipped with two servicing valves; one is the typical liquid receiver service valve mounted between the liquid receiver and the liquid line, the other is a second liquid receiver service valve which is installed between the liquid receiver and the condenser. These two valves enable one to disconnect the liquid receiver or the condenser from the system separately. All receivers are equipped with safety devices. The minimum safety device is a thermal release plug while some receivers have both the thermal and pressure releases. A special line may be installed to carry any released gas outdoors.

These cylinders are usually of cylindrical form mounted either in a vertical or horizontal position. The horizontal style is usually suspended underneath the compressor and motor frame.

Some companies are now providing

these liquid receivers with a device whereby the level of the liquid refrigerant may be easily determined.

In the construction involving a water coil inside the liquid receiver the shell is similar to the one just explained, but it is usually larger for the same size compressor unit.

The connections where the water-cooling coil enters the tank may be either brazed or soldered. Brazing is preferred because of its greater mechanical strength.

19-14. COMMERCIAL COOLING UNITS

Because of the great variety of demands in commercial refrigeration, special cooling unit designs are required for many installations. These cooling units vary from coils of tubing immersed in a sweet water bath to forced circulation cooling units which have the air driven over the coils by means of an electric fan.

Cooling coils may be divided into two main divisions:

1. Those that are used for cooling air which in turn cools the contents of the cabinet.
2. Those that are submerged in a liquid such as brine or a beverage which is to be consumed.

Coils for cooling air are of two types. The most popular for most applications is the natural air convection coil. In this type the air circulation depends only on gravitational circulation. The three different classes of natural convection, air cooling coils are:

1. The frosting type of coil
2. The defrosting type of coil
3. The non-frosting type of coil

It is the condition under which a coil operates which determines under which of the above classifications a particular coil falls. The governing conditions are the desired temperature range of the cabinet and the temperature difference between the coil and the cabinet. Any particular coil may be operated under any of the above conditions; i.e., frosting, defrosting, or non-frosting. However, in air-conditioning and in some other installations, non-frosting forced circulation air-cooling coils are becoming the only ones used.

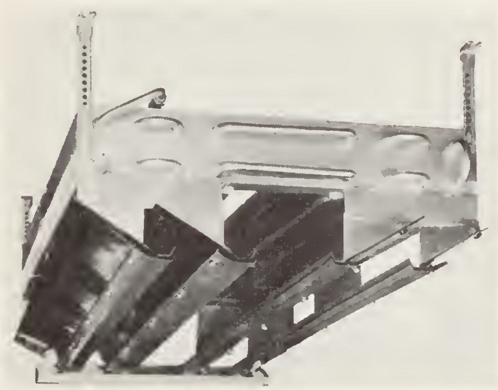
19-15. FROSTING TYPE COOLING COIL

The frosting type of coil was the first one produced by the refrigerating companies for use in cabinets of all kinds. The coils were of the low side float control type and consisted of a very small amount of fin area held at a very low temperature. These coils never become warm enough (over 32 F.) to allow the frost accumulation to melt. These units were constructed of coils of seamless copper tubing brought out of the low side float chamber and run back into the same chamber. To these coils were soldered large copper fins. The coils were usually all soft soldered. The fins were of thin copper sheet (.015-inch to .025-inch) reinforced around the edges and aligned with thin strips of metal. The cooling coils were usually tinned, or in some other way were made non-corrosive. These coils had to be manually defrosted, as the gradual accumulation of ice on the fins of the coil decreased the heat removing capacity of the coil tremendously. The frost which formed on the coils came from moisture in the air. This withdrawl of moisture from the air left it dry, and the dry air in turn rapidly dried out the food in the cabinet.

19-16. DEFROSTING COOLING COIL

To eliminate the difficulties encountered in defrosting the frosting type coils, companies have produced

a coil which may be classified as the defrosting type. This coil is used with the thermostatic expansion valve refrigerant control. The area of the coil is increased so that it will behave as follows: during the running of the compressor this coil will stay at a temperature of 20 F. to 22 F. This will cause a frost accumulation on the coil, but after the compressor stops, this



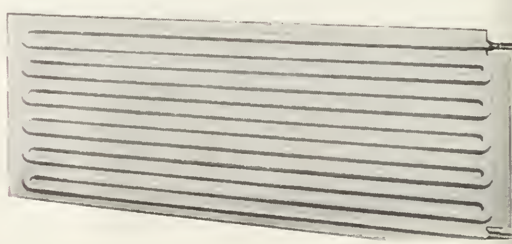
19-20. A non-frosting coil. Note the provisions for removing the condensate.
(Bush Mfg. Co.)

coil warms up enough so all the frost melts from the coil before the compressor starts again, Fig. 19-19. This arrangement works in some installations, but in others it may present some problems. It appears that during the off part of the cycle the top of the coil may defrost and its moisture run down the fins, but before the moisture has time to escape it often freezes around the lower parts of the fins. This ice accumulation on the bottom fins may block the air circulation around the coils and interfere with proper refrigeration.

19-17. NON-FROSTING COIL

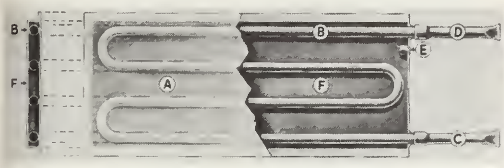
Because of the troubles experienced with frosting coils some companies are producing non-frosting coils. These coils use only the thermostatic expansion valve type of refrigerant control. The construction is such that the area of the coils is so great that in order to cool the box down to 36 F. to 38 F. these coils need never become colder than 21 F. to 32 F. which naturally allows them to be named non-frosting. However, the refrigerant inside the coil usually operates at 20 F. or 22 F. to produce this surface temperature. See Chapter 21. Occasionally these coils accumulate a very slight coat of frost just before the compressor shuts off, Fig. 19-20. This frost disappears, however, immediately after the compressor stops. The big advantage of this type of coil is the fact that since it is not at a temperature below freezing itself it does not have a tendency to draw the moisture out of the air very rapidly; therefore it is possible to maintain a 75 per cent to 85 per cent relative humidity in the cabinet, which is the amount required to keep the produce fresh and to keep it from losing weight. Non-frosting coils are slightly more bulky than the frosting types. These coils should be baffled to direct the flow of air around them. The baffling should be so constructed that the air will flow continually in one direction past the coil. Baffling tends to speed up the cooling of the air and makes the coil more efficient, but it does occupy some space. See Chapter 21 for baffle design.

Cooling coils are sometimes classified according to their construction. The two most common constructions



19-21. A plate type cooling coil.
(Kold Hold Div., Tranter Mfg. Co.)

are the tube and fin type, and the plate type. As explained in Chapter 21, that part of the cooling coil contacting the air needs more surface than that part in contact with the refrigerant. The fins and the plates are means to furnish more air contact surface. Figure 19-21 illustrates coil made of two plates with one plate formed into grooves for recesses. When the two plates are fused together a plate-type cooling coil is formed. Another type plate coil is shown in Figure 19-22. It uses refrigerant tubing mounted between two plates. A vacuum is created between the plates to create a tight contact between the tubing and the plates.



19-22. A plate type cooling coil in which additional surface is obtained by attaching plate to copper coils. (Dole Refrigerating Co.)

Some of these coils have an eutectic solution between the plates. This solution freezes at a certain pre-determined temperature and therefore produces a long contact refrigeration temperature.

19-18. FORCED CIRCULATION COOLING COIL

Forced circulation cooling coils consist of a compact arrangement of refrigerant cooled tubes and fins about which air is blown by means of an electric fan. Both the coil and the fan are usually enclosed in a metal housing. These coils have the advantage of taking up a very small amount of space and do not need any special or extra baffling, Fig. 19-23. They do, however, have a tendency toward rapid dehydration of foods unless special care is taken. If the coil is large and operates at a small temperature difference (10 F. to 12 F.) and the air is circulated slowly, there is less tendency to dehydrate foods.

In installations in which dehydration is not important, small coils may be used operating at a high temperature difference (20 F. to 30 F.), and the air may be blown rapidly through the coil. Thermostatic expansion valve refrigerant controls are usually used with forced convection coils.

The motor which drives the fan may be from 1/50 H.P. and up, and may run continuously, or may be controlled by the coil or the box temperature. The refrigerant temperature is usually held quite low, but the coil does not frost because of the rapid air circulation, Fig. 19-24. However, considerable sweating does occur and facilities for drainage must be incorporated in the installation.

A coil of this kind is noted for the rapidity with which it will cool a refrigerator cabinet. One can almost neglect the heat leakage in calculating the "pull down" time for this type of coil. In storage cabinets used for

19-23. A blower coil designed for mounting in the corner of a refrigerator. Note the small amount of space required. The air enters at the bottom, is cooled and exits at the front. The unit requires a liquid line, a suction line, an electrical line, and a drain pipe. (Refrigeration Engineering, Inc.)

bottle beverages, for foods in sealed containers, and for air-conditioning work this forced convection cooling coil is very popular.

One major problem with the condensate is removing it from the drain pan to the nearest drain. Drain connections are built into all the drain pans and copper tubing is usually used to carry the condensate away. However, in many cases the drain does not work well enough due to the small size of the drain or because the slope of the drain is not enough.

A positive method to drain the condensate, even in large amounts during defrosting is to use a condensate pump, Fig. 19-25. This pump is mounted on the drain pan and is self priming. It operates continuously and uses about 10 watts.

19-19. COOLING COIL DEFROSTING

Many cooling coils operate at temperatures below freezing. The demand for open display cases and frozen foods has necessitated many low temperature installations. These coils operate at refrigerant temperatures of 0 F., -10 F., and even -20 F. Blower coils are used in many cases at these low temperatures and their small fin spacings makes frequent defrosting necessary. Other type coils also need defrosting even though not so frequently.

It is desirable to defrost these coils without disturbing the fixture temperature markedly. If the coils are not defrosted frequently, the frost accumulation will soon make the cooling coil inoperative.

It is very important that the user still be strongly reminded to clean the coil, the drain pans and the drain lines frequently to prevent detrimental odors. A soda solution may be used.

These coils are usually defrosted automatically. A time clock control either turns on the defrosting mechanism once each day or turns on the defrost system after so many hours of compressor operation.

The types of defrosting mechanisms are as follows:

1. The hot refrigerant gas system
2. The non-freezing solution system
3. The water system
4. The electric heater system

19-24. A forced circulation cooling coil with the fan unit removed.
(Refrigeration Engineering, Inc.)

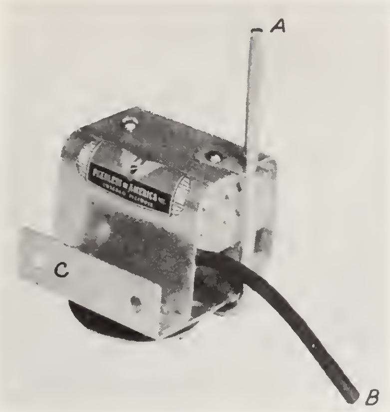
5. The reverse cycle defrost system
6. The warm air system

These defrosting devices either heat the coil internally (from the inside) or externally (from the outside).

19-20. HOT REFRIGERANT GAS DEFROST SYSTEM

The hot gas system consists of pumping the hot refrigerant gas from the compressor directly through the cooling tubing. It consists of a refrigerant line running from the compres-

sor exhaust line up to the cooling coil and connecting this line into the system between the thermostatic expansion valve and the cooling coil. The operation of this line is controlled by a solenoid shut off valve, mounted in it.



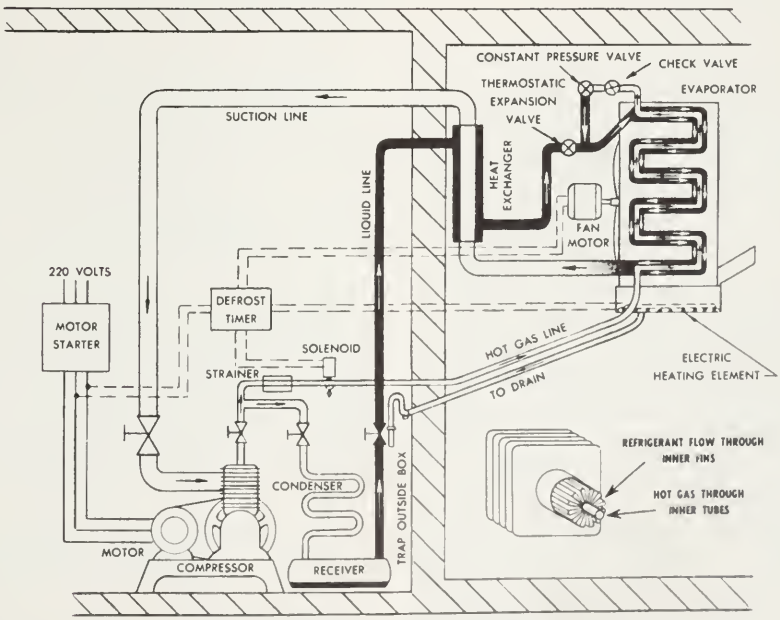
19-25. A condensate pump for use on cooling coil drains. A. Condensate outlet; B. Electrical leads; C. Mounting Bracket.
(Peerless of America, Inc.)

At the predetermined time (usually set at 12 midnight or 1 A.M.), the time clock closes a circuit which starts the compressor, opens the solenoid valve and stops the fan motors. The hot gas rushes through the cooling coil (warming it) and then back to the compressor along the suction line, Fig. 19-26.

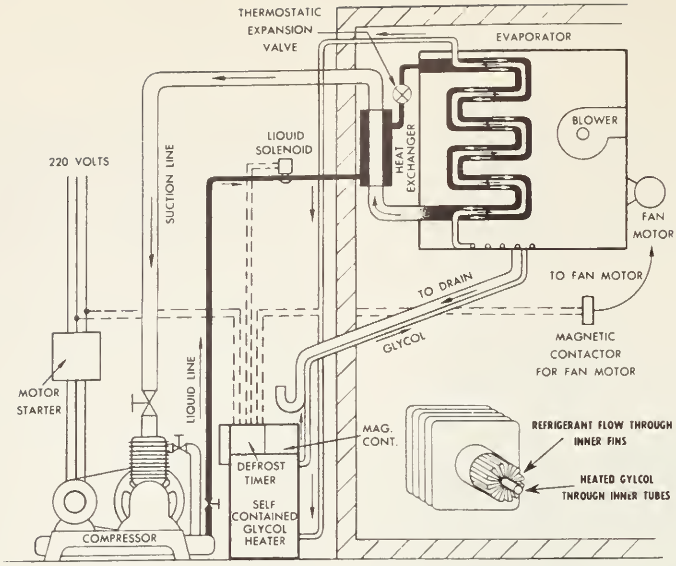
This system will usually defrost the coil in 5 to 10 minutes of operation. To keep the defrost water from freezing in the drain pan and tube, part of the defrost line is installed under the drain pan to keep it warm.

It is best to evaporate the refrigerant that condenses in the cooling coil during the defrost cycle. Heat is applied to the returning refrigerant (electric in some cases) to do this vaporizing. In the illustration, a special blower evaporator is installed in connection with the suction line and the air forced over this re-evaporator insures that only gas can get back to the compressor. This blower works only while the unit is on defrost.

A suction line pressure reducing valve (a regulating valve) is installed



19-26. A hot gas defrosting system.
(Bush Mfg. Co.)



19-27. A defrost system with a non-freezing solution tank to furnish heat for re-evaporation of the return refrigerant.

in the suction line to keep the low side pressure of the gas going to the compressor at a safe pressure level.

It is very important that slugs of refrigerant be prevented from entering the compressor. Re-evaporation should be as thorough as possible.

19-21. NON-FREEZING SOLUTION SYSTEM

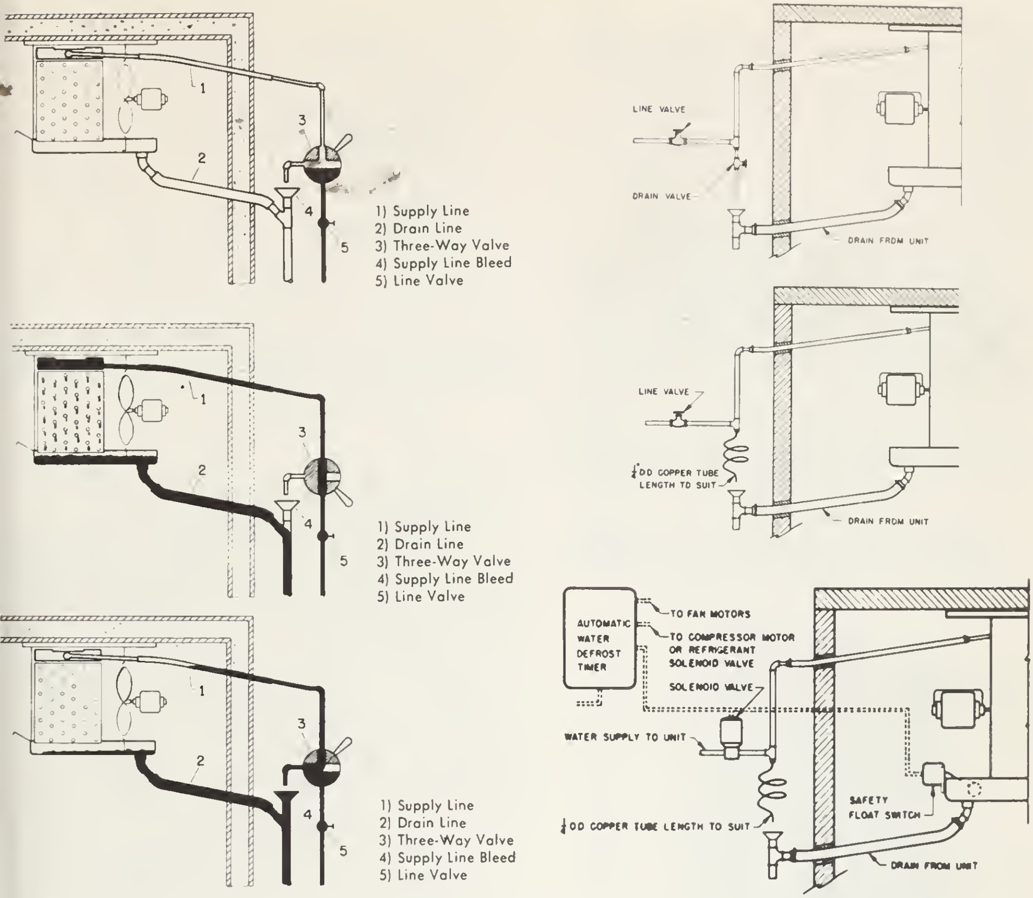
A system that has been used for years is a hot gas defrost system that uses a special cabinet in which a brine is stored. The refrigerant gas from the compressor is pumped through this heat storage unit before it goes to the condenser. The brine is therefore heated during the normal cycle. An oil trap is also installed in this part of the system to insure oil return to the compressor. Some systems heat the brine from a separate heat source. Electrical heating elements are usually used. The heaters are normally energized only during defrosting.

To defrost the system, the defrost timer opens a solenoid valve in a line running from the condenser line to the cooling coil just on the cooling coil side of the thermostatic expansion valve. The refrigerant returns to the compressor in the original suction line. However this line is usually heated. One system is to run it through the top of a cylinder immersed in the stored heat liquid solution in the tank. Any liquid refrigerant in the return refrigerant is trapped in the lower end of the inside tank and it is evaporated by the heat in the solution in the outer tank, Figure 19-27.

The heat exchanger is insulated to help retain the heat that is stored in the non-freezing solution.

19-22. WATER DEFROST SYSTEM

The water defrost system either manually or automatically runs tap water over the cooling coil and turns off the refrigerator, Fig. 19-28. The water is warm enough to melt the ice and the water is drained away by means of the cooling coil drain pan. It is important to drain the water from the water lines before this water can freeze. The water is sprayed over the cooling coil or it is fed to a pan located over the coil and holes in the



19-28. A water spray defrost system in operation and showing three methods of installing. (Refrigeration Engineering, Inc.)

pan feed the water evenly over the coil.

The system uses an electric timer for automatic operation, Fig. 19-29.

Some special systems have been designed to defrost by spraying a brine over the cooling coil. A lithium chloride brine has been successfully used. The brine is recirculated by means of a pump. Eliminator plates are needed to prevent brine spray from passing into the refrigerated space.

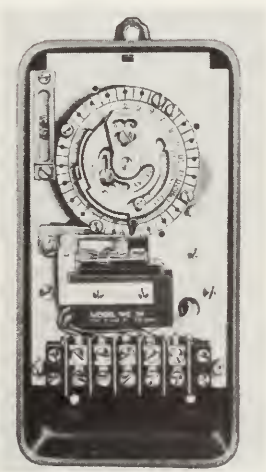
19-23. ELECTRIC HEATER DEFROST SYSTEM

Another popular method used for defrosting low-temperature coils is to use electric heat. Electrically heated coils are installed in the cooling coil, around the coil or within the refrigerant passages to furnish heat to defrost the cooling coil.

One electric type uses resistance wire heating elements mounted underneath the cooling coil and also under the drain pan and along the drain pipe. A timer stops the refrigerating unit, and the blowers and the electric heaters are turned on. The heat from the heaters quickly melts the frost from the coil and the water formed drains away. When the coils are warm enough to insure that all the frost is gone a thermostat returns the system to normal operation.

Another electric defrost system uses an immersion type electric heater to heat a separate charge of refrigerant. This warm refrigerant then circulates around the cooling coil in its own passageways to warm the cooling coil and defrost the system while the refrigerating unit is turned off.

Still another application of the electric heater defrost system is to use a double tube cooling coil. The cooling coil refrigerant passes through the passageway between the tubes during normal refrigeration. When defrosting is needed, the system is stopped and electric heating elements inserted in the center tube heat the cooling tubes and cause defrosting from the inside. Fig. 19-30.

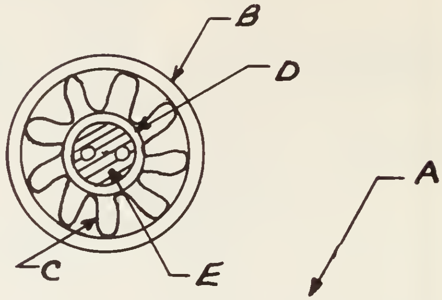


19-29. An automatic timer used with water defrost systems.
(Paragon Electric Co.)

19-24. REVERSE CYCLE DEFROST SYSTEM

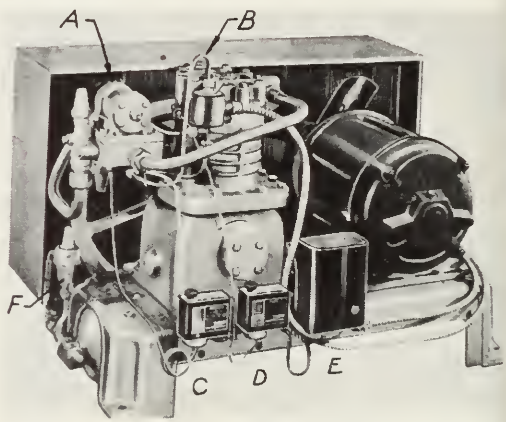
Another system used to defrost a coil is to reverse the flow of refrigerant in the system and therefore make the cooling coil become the condenser and make the condenser become the cooling coil.

This reversing is accomplished by installing a four way valve, two check valves and an automatic expansion valve in the system, Fig. 19-31.



19-30. An electric defrost system with the electric heating elements installed within the coil tubing. A. Fin; B. Outer tube; C. Inner fin; D. Inner tube; E. Heating element.

To operate on defrost, the four way valve is turned, either manually or automatically and the hot gas from the compressor travels up the suction line, heating the cooling coil by condensing in it and by-passes the thermostatic expansion valve through one of the check valves. It then passes through the receiver and is then throttled by the automatic expansion valve (the check valve at this point prevents by-passing the expansion valve). The refrigerant boils in the condenser and



19-31. A reverse cycle defrost system condensing unit. This condensing unit is connected to a blower coil equipped with a thermostatic expansion valve with a check valve controlled by-pass. A. Four-way valve; B. Solenoid pilot valve for the four-way valve; C. Fan delay control; D. Low pressure control; E. Timer control; F. Expansion valve which operates when unit is on defrost and when the condenser becomes a temporary cooling coil.
(Lehigh Mfg. Co.)

is returned to the compressor in a gaseous state. The automatic expansion valve is adjusted to maintain a maximum safe low side pressure to prevent freezing temperatures in the condenser.

The liquid receiver is designed to permit the reverse flow of gas to travel over the reserve liquid in the receiver and not return it to the condenser. See Chapter 26 for more detail on reverse cycles.

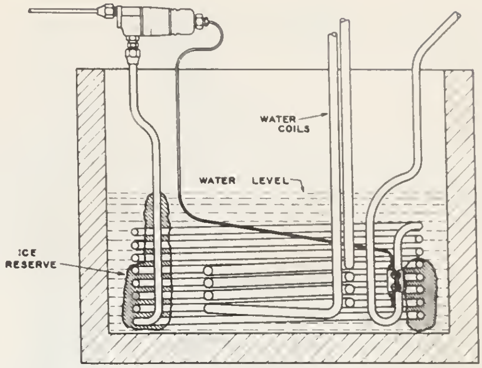
19-25. WARM AIR DEFROSTING

Where sufficient warm air is available, it can be used to defrost low temperatures coils. If the cabinet air is warm enough, it can be used for defrost purposes. The cycles must be frequent enough and often enough to defrost the coil completely.

Some installations bring in outside air to perform the defrosting by using a duct system with blowers and a fan.

19-26. IMMERSED COOLING COIL (BRINE)

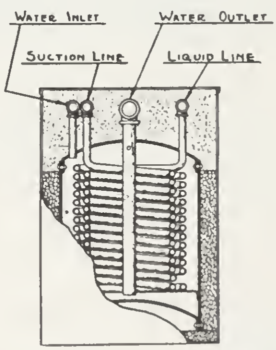
The other big field of commercial cooling coils is the immersed type, where the coils are surrounded by calcium chloride or alcohol brine. A small plain, tube-cooling coil submerged in this brine has very good heat transfer. The efficiency of these coils is greatly increased because of the fact that liquids transfer heat to metals much faster than air can transfer heat to metals; a ratio of 50 or 100 to 1. That is, a submerged coil can remove 50 to 100 Btu per hour, per degree temperature difference, per square foot of coil surface, whereas air-cooling coils can remove only 1 Btu under the same conditions. These coils may use either a low side float or a thermostatic expansion valve refrigerant control when used in multiple installations.



19-32. A sweet water bath brine. The ice accumulation is controlled by the location of the thermostatic expansion valve feeler bulb.
(Detroit Controls Corp.)

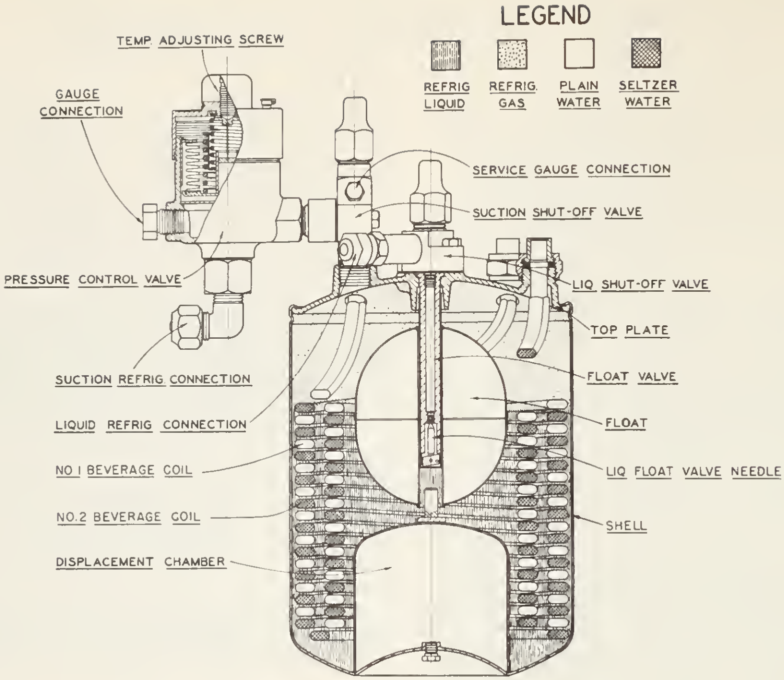
19-27. IMMERSED COOLING COIL (SWEET WATER)

Another type of submerged cooling coil is a coil submerged in ordinary tap water which is termed a sweet water bath. The common example of this type is the water-cooling device used in soda fountains. The cooling coil is submerged in the sweet water, and another coil in which the water is to be cooled and consumed by the customer is also submerged in this same water.



19-33. A pressure type beverage cooler. The refrigerant coils are submerged in the beverage to be cooled.
(Filtrine Mfg. Co.)

It is the feature of this design to allow this sweet water to freeze a little around the coil during what is



19-34. A beverage cooling coil, for two different beverages, using a low side float refrigerant control. (Temprite Products Corp.)

called the non-load period. This light ice accumulation around the cooling coil will act as a storage reserve of refrigeration. These systems use the thermostatic expansion valve, Fig. 19-32. In the event a thermostatic expansion valve refrigerant control is used the thermostatic bulb should be clamped to the outlet of the coil. The coil should reach to the bottom of the bath if the temperature of the bath is to be less than 39.1 F. Water between 39.1 F. and 32 F. tends to expand and rise. Therefore, the coldest water, between these temperatures, will be at the top.

19-28. PRESSURE TYPE BEVERAGE COOLER

A type of cooling coil which may be classed as the submerged type is the pressure type beverage cooler. In this cooling coil the liquid refrigerant is carried in a tube submerged in the beverage to be cooled. Its construction is similar to that of the liquid receiver type of water-cooled condenser. This construction is quite common for instantaneous water coolers, Fig. 19-33. A precaution to be observed in this type is that the temperature of the beverage should never be such that it will freeze to any extent.

Another type of submerged cooling coil design is illustrated in the beverage cooler made by the Temprite Cooler Corp. This unit consists of a coil of tubing, carrying the beverage to be consumed, submerged in a quantity of liquid refrigerant. The liquid refrigerant is controlled by a low side type float, Fig. 19-34.

A beverage cooling coil that takes advantage of the high heat conductivity of aluminum is the all-metal beverage cooling coil made by the Heat-X Division, of the Bush Mfg. Co.

Two separate copper tubes are coiled in a helix design and they are then put in a permanent mold and liquid aluminum is poured into the mold. After solidification the two tubes are com-

pletely encased in a hollow cylinder of aluminum. The heat transfer is excellent. If refrigerant is evaporated in one coil, heat will flow from whatever liquid may be flowing in the other coil, Fig. 19-35.

The surrounding of the tubing by the casting produces an extremely strong coil that can survive freezing of water in the tubes.

Stainless steel tubing is also used as one of the tubes when beverages that require that metal are to be refrigerated.

Some of these coolers have three or more separate tubes encased by the aluminum when more than one liquid is to be cooled.

19-29. HEAT EXCHANGERS

To increase the efficiency of operation of larger commercial units and air conditioning comfort cooling installations, a heat exchanger is often mounted in the liquid and suction line.

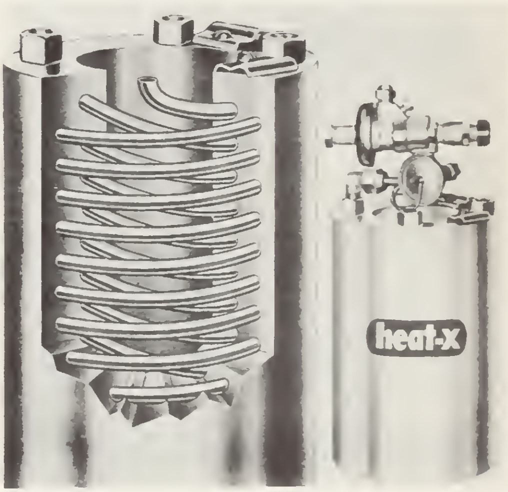
A heat exchanger, as the name indicates, provides for a heat transfer from the warmer liquid in the liquid line to the cool gas coming from the cooling unit. A study of Fig. 19-36 will show that if the liquid is cooled 10 to 20 F. at the prevailing head pressure and as it passes through the refrigerant control the liquid can absorb more latent heat as it changes to a gas.

The reduction of "flash gas" is important. Vaporized refrigerant which comes from the instantaneous change of some of the liquid to a gas as the refrigerant passes through the refrigerant control reduces the valve capacity, increases the low side pressure drop, and reduces the amount of heat each pound of refrigerant can absorb as it evaporates. The flash gas is developed by some of the liquid vaporizing to cool the remainder of the liquid to the evaporating temperature. The heat exchanger cools the liquid refrigerant and reduces the flash gas and the heat from the liquid helps prevent sweat backs or frost backs on the suction line.

It is essential that the heat exchanger be large enough to allow sufficient heat transfer and they should not increase the low side pressure drop appreciably.

The heat exchangers are rated on the Btu capacity of the system.

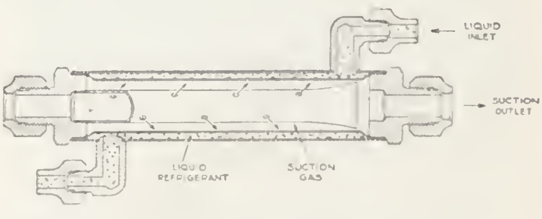
When installing a heat exchanger one should specify the refrigerant, the units Btu capacity and the size of the liquid and suction lines.



19-35. A dry type beverage cooling coil. The aluminum casting surrounds the refrigerant coils and the beverage coils and permits rapid heat transfer. The refrigerant control used is a thermostatic expansion valve. (Bush Mfg. Co.)

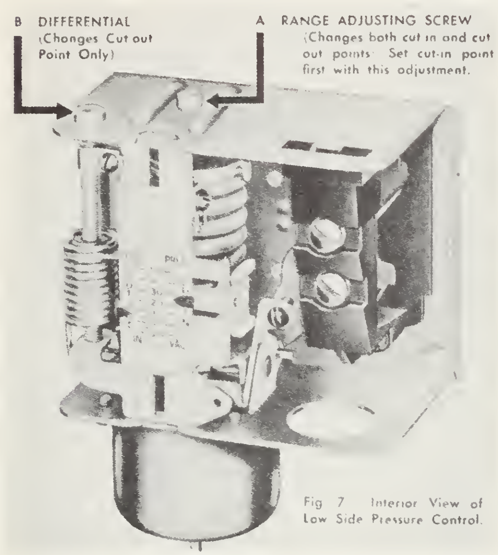
19-30. REFRIGERANT CONTROLS

For single installations involving



19-36. A heat exchanger used on commercial systems. (Mueller Brass Co.)

one cooling unit and one condensing unit the five types of refrigerant controls that can be used are: automatic expansion valves, thermostatic expansion valves, high side floats, low side floats and capillary tubes. These are explained in Chapter 5. As previously mentioned, in multiple installations which cover a greater magnitude of uses, the only two types of refrigerant controls usable are the low side float and the thermostatic expansion valve. Thermostatic expansion valves are used almost exclusively, but there are a few low side float systems still in use.



19-37. A pressure motor control used on commercial installations.
(Penn Controls, Inc.)

The thermostatic expansion valve is explained in Chapter 5. One should study their design, operation, installation, care and repair before proceeding with this chapter.

19-31. MOTOR CONTROLS

The two basic types of motor controls used in commercial refrigeration are identical to those used in domestic refrigeration, namely, the pressure motor control, and the thermostatic motor control.

In multiple commercial work, pressure motor controls are the most popular. The reason for this is that the low side pressure is an indication of the temperature in the coil, and one control works well regardless of the number of coils connected to it, Fig. 19-37. These controls provide both range and differential adjustments. Explanation of the various range and differential adjustments will be found in Chapter 6.

The control consists of a switch built into a toggle arrangement which is acted upon by a bellows whose pressure may be either temperature, or pressure operated. As the pressure in the bellows builds up, the toggle is snapped and the switch contact points close, starting the motor.

The current draw of the larger motors is enough to make a motor starter necessary for A.C. motors of single phase of over 1 H.P. All three-phase A.C. motors require a starter. This electrical work should be done by a licensed electrician and the work should strictly follow the local electrical code requirements.

As the compressor runs, it reduces the temperature, or the pressure on the bellows, until the toggle is snapped the other way, opening the switch and stopping the motor.

These controls have a range adjustment which is usually an adjustable spring pressing against the bellows. When the spring pressure against the bellows is increased, the cut-in and cut-out points are raised equally. The range adjustment controls the cabinet temperatures desired, Fig. 19-38.

The distance between the cut-in and cut-out points registered either in degrees F. or in pounds per square inch is called the differential. It is an adjustment which controls the amount or

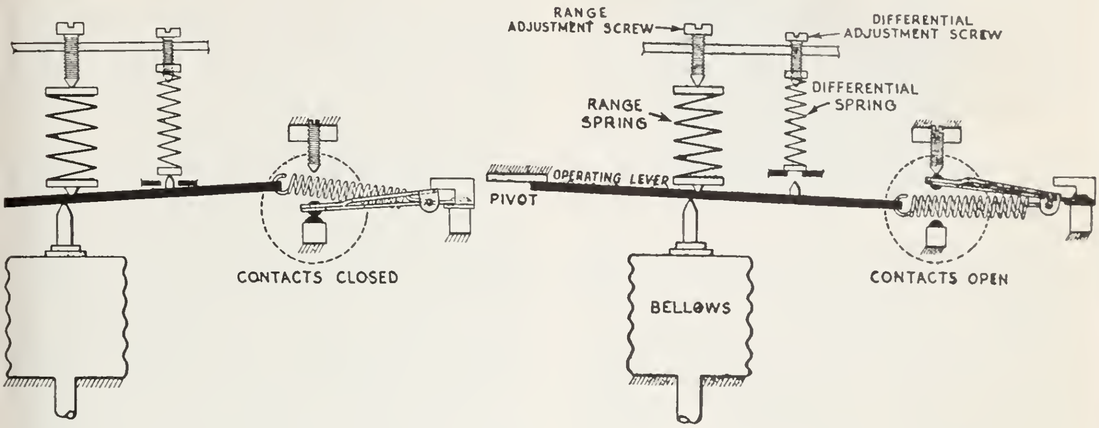
the distance the toggle snaps. The differential controls the cycling interval. The three types of differential adjustments are:

1. Adjusting cut-out only.
2. Adjusting cut-in only.
3. Adjusting both (either putting them farther apart or closer together).

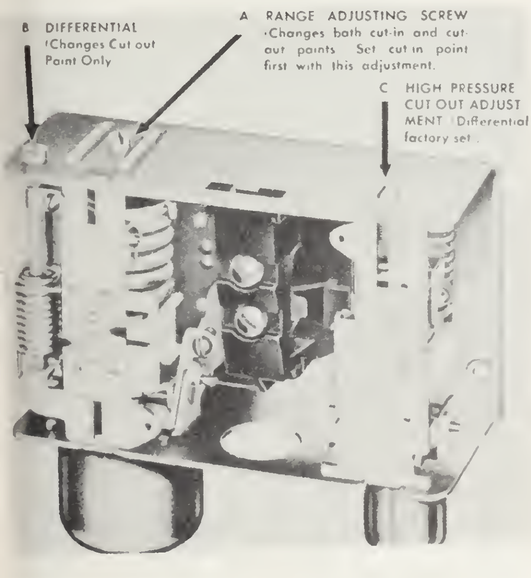
See Chapter 6 for detailed explanation of motor control operation.

19-32. PRESSURE MOTOR CONTROL

This control is usually located on the condensing unit, and the low side pressure operates the mechanism.



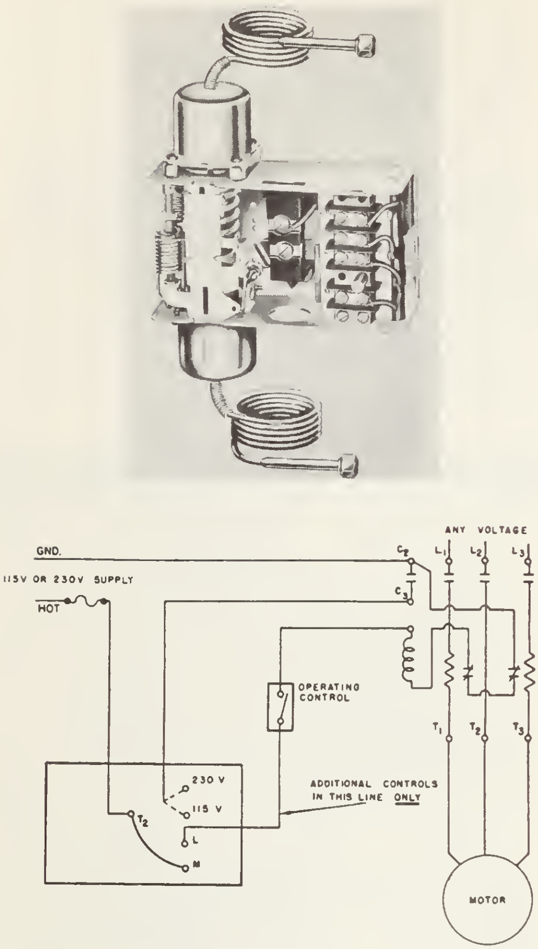
19-38. A schematic diagram showing operation and adjustments of pressure motor control. (Frigidaire Div., General Motors Corp.)



19-39. A pressure operated motor control with a high pressure safety cut-out. (Penn Controls, Inc.)

Some companies recommend tapping into the low side suction line about 10 to 15 feet from the compressor for this control, Fig. 19-39. The range settings vary with the application. The cut-out pressure should correspond to a temperature approximately 10 F. below the desired coil temperature, while the cut-in pressure should correspond approximately to the coil temperature.

The differential setting will vary depending upon the temperature accuracy desired. A wide pressure difference will allow some variation in cabinet temperature and will lengthen the cycle interval of operation of the condensing unit. A differential set to close limits will maintain a more uniform cabinet temperature but will shorten the cycling interval of the condensing unit. A pressure difference between the cut-in and cut-out point commonly used is ap-



19-40. An oil pressure safety cut out for large commercial systems.
(Penn Controls, Inc.)

proximately 15 psi for methyl chloride, and 20 psi for Freon-12.

Remember to use 2 inches of mercury vacuum equal to 1 psi.

19-33. THERMOSTATIC MOTOR CONTROL

The thermostatic motor control is similar to the pressure control in construction and arrangement except for the power bulb and capillary tube. This control is usually used only in large sized single installations. However, satisfactory set-ups have been made in multiple installations which assume that, when the one controlled cabinet has cooled sufficiently, the others have also.

The thermostatic motor controls are popular in brine cooling installations with the power element submerged in the brine. Ice cream cabinets are a typical example. When used in single cabinet installations the power element is usually mounted in the cabinet four feet up from the floor between the cold and warm air flues and at least two inches from the wall.

An innovation in multiple installations involving an ice cream cabinet is that a pressure motor control, located on the condensing unit, and a thermostatic motor control, located on the ice cream cabinet, are connected in parallel to make the condensing unit operate until both the ice cream cabinet temperature and the low side pressures are low enough. It is only when both controls are open that the unit will stop.

19-34. SAFETY MOTOR CONTROLS

An important difference between commercial and domestic controls is the fact that commercial controls incorporate safety devices known as (1) a high pressure safety cut-out, (2) an oil pressure safety cut-out.

The high pressure safety device consists of a bellows built into the control and connected to the high pressure side of the system. It is frequently connected to the cylinder head to permit easy disconnecting of the control from the system. This bellows is attached to a plunger in such a manner that if the head pressure becomes too high due to air in the system, the condenser water being shut off, or other causes, this bellows will expand, push the plunger against the switch, and shut off the motor.

This control is called a safety device because its action prevents the

building up of dangerous pressures within the system; more important still is the fact that it prevents ruining the motor through over-loading and over-heating. These controls are usually set to cut-out at about 125 psi pressure, except in Freon-12 systems, in which case the control is set at about 150 to 160 psi.

The oil pressure safety cut-out is a safety device that will shut off the electrical power if the oil pressure fails or dips below normal. It is a differential control, using two bellows. One bellows responds to the low side pressure and the other responds to the oil pressure. The control will open the circuit if the pressure difference between the two bellows drops below the required oil pressure needed, Fig. 19-40. This control is used in the larger commercial systems. When the pressure difference is too low the mechanism sends the current through a bi-metal strip and if this strip heats up before the pressure returns to normal, the power is disconnected.

19-35. DUAL MOTOR CONTROLS

Keeping good refrigeration temperatures with good humidity characteristics, and without excessive frosting of the cooling coils, has always been an engineering problem in commercial refrigeration. Recently several methods have been devised to alleviate the situation.

Controls have been designed which operate on the principle of using the cabinet temperature to produce the cut-out and the coil temperature to produce the cut-in. This insures correct cabinet temperatures before the unit stops and a defrosted coil before the machine starts on every cycle while maintaining good humidity characteristics. The control may be used either in single or multiple installations.

A control called the "Polartron," which uses a thermostat in conjunction with a holding coil to obtain correct cabinet temperature on the cut-out while a pressure element, also connects to the control and controls the cut-in point and thereby determines that the frost on the coils will melt away on each cycle. This control also incorporates a high-pressure safety cut-out which will not allow the machine to start unless the head pressures are down to normal. An overload relay provided for safety in case of excessive motor loads.

A commercial motor control was developed which solves the problem of maintaining good refrigeration temperatures during low ambient temperature periods (ambient temperature refers to outside, i.e., surrounding temperature). This action is accomplished by cycling the unit with the high-pressure control. If the condensing pressure falls to a certain level, due to the cooling action of the ambient temperature, the condensing unit will cut-in, thereby cycling the unit, even though the low-pressure cut-in may not have been reached in the cabinet. This more frequent cycling eliminates the spoilage film that sometimes forms on meats if an ordinary control is used under these conditions.

19-36. MOTOR STARTERS

The control contacts (open or sealed) are limited to the amount of current they can carry safely. The National Electric Code and the local electric codes usually specify the limitations of these controls.

However, these same commercial controls can be used for larger motors (larger loads) by using a device called a magnetic starter.

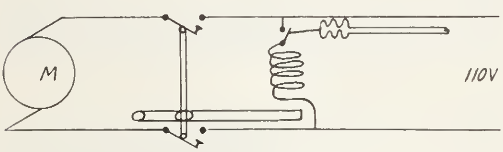
The magnetic starter is an electromagnetic device. The magnetism is controlled by the electricity that flows through the motor control. The magnet-

ism attracts a piece of steel (or armature) and when this armature moves, it closes large contact points that safely carry the large currents needed for the large motors, Fig. 19-41. These starters are mounted in an approved metal box with a safety access door. Some of the units incorporate a manual shut off switch, fuses and an overload thermal safety breaker. The safety switch is a heating element located in the motor line. If the motor demands too much current (shorts, grounds, or overloads) this heater will cause a thermal bimetal strip to bend, opening the electromagnet circuit, which in turn will open the main switch.

19-37. DEFROST TIMERS

The automatic defrosters require an automatic device for starting the defrost cycle. In installations which use a defrost timer an electric self-starting clock mechanism is used to operate a cam which actuates the switches, Fig. 19-42.

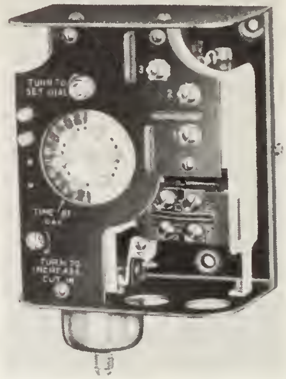
Some of these time clocks are connected directly to the electric power



19-41. A schematic diagram of an automatic control on a magnetic starter.

and will defrost the system at the intervals necessary to maintain an efficiently operating coil. Some coils need to be defrosted every few hours, while some coils need to be defrosted only once each day. The cams can be adjusted to control the length of the defrost cycle.

Some of the timers are connected to the electric power in parallel with the motor. The clock mechanism only registers the running time of the condens-



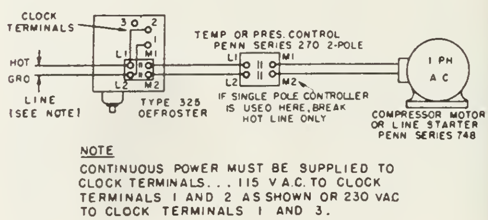
19-42. A timer used to operate the defrost cycle. (Penn Controls, Inc.)

ing unit. These mechanisms also are adjustable for starting the defrost cycle based on hours of running time, Fig. 19-43.

The timer wiring differs according to the type of defrost system. In one hot gas system, the timer energizes the solenoid valve, stops the fan motors, energizes auxiliary electric heater elements, runs the compressor, etc. It also may be used to prevent the normal cycle from starting until the low side pressure is reduced to normal levels.

An electrically operated timer is shown in Fig. 19-44. The control can be used with any type defrosting system. The defrost "off" time is adjustable from 15 to 120 minutes (lower left). The buttons on the dial determine the starting time of each defrost cycle.

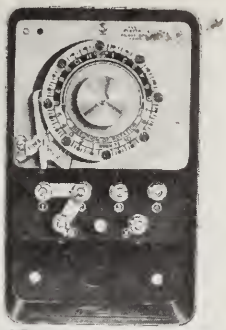
Another type of automatic timer for defrosting is shown in Fig. 19-45.

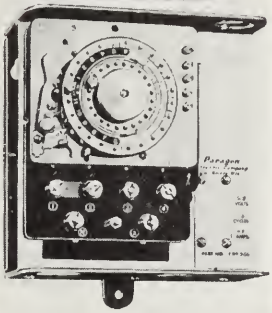


19-43. A diagram of a defrost timer circuit. (Penn Controls, Inc.)

This unit is electrically connected to an external pressure control or thermostat so at a predetermined time starts the defrost. A pressure setting or temperature setting operates a solenoid to end the defrost time. The control has a fail-safe device which will turn the refrigerating unit on again after a certain time interval if the pressurestat or thermostat do not run it on.

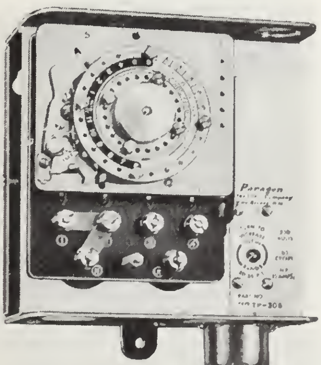
A timer that can be used with either hot gas or electrical heat is shown in Fig. 19-46. It uses the timer motor to start the defrost action and a pressure control connected to the low pressure side of the system is used to return the system to normal operation.



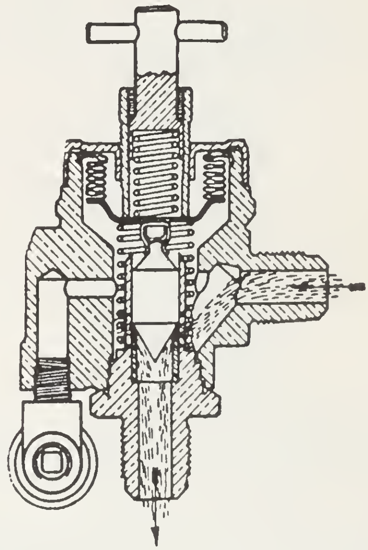


19-44. An automatic timer that may be used to control any type of defrosting system.

19-45. An automatic timer that is used with pressurestat or thermostat to control return to normal operation. The control can also be operated on time only. It also has a safety device for starting the refrigerating. (Paragon Electric Co.)



19-46. A defrost timer that has a pressure attachment which operates from the low pressure side. The timer starts the defrost action while the pressure device returns the system to normal operation. (Paragon Electric Co.)

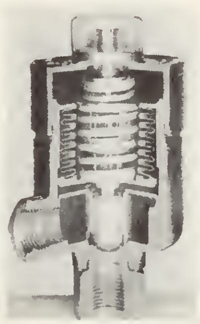


19-47. A two-temperature valve. (Fedders Mfg. Co.)

19-38. TWO-TEMPERATURE VALVES (PRESSURE CONTROL)

In many multiple installations it is necessary to maintain different temperatures in the various coils connected in the same system. Thermostatic expansion valves may be used if the temperature differences are not too great (not over 5 F.) but in some instances, such as with a storage cabinet and an ice cream cabinet combination, the temperature differences are

too great to be taken care of in this manner. To provide for this a two-temperature valve is put into the suction line; it operates in such a manner that it prevents the pressure of the warmest coil from going below a predetermined setting. These valves are sometimes called constant pressure valves or pressure reducer valves. The valves sometimes are used to insure a constant low side pressure. Their construction consists of a bellows, a needle, and seat arranged in such a way that the bellows is actuated by the pressure in the warmest coil, Fig. 19-47. As the compressor pumps the low side down to this predetermined



19-48. A metering type two-temperature valve. (Temprite Products Corp.)

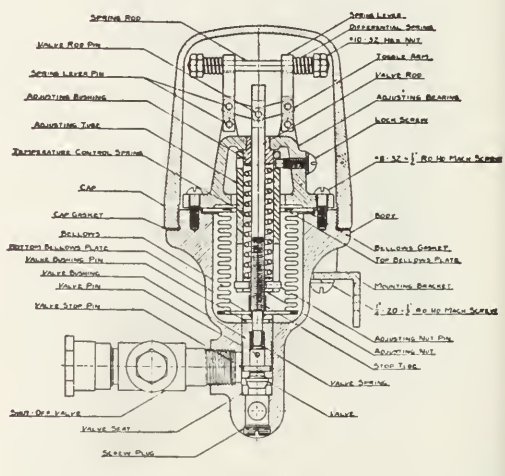
pressure, the bellows shuts off this valve, preventing the pressure in the warmest coils from going below the pressure desired. As the pressure in the coil builds up, due to the vaporizing of the refrigerant in the coil, the bellows again opens the valve allowing the gas to travel to the compressor.

Since the pressure maintained upon the surface of a quantity of liquid refrigerant determines the temperature at which the refrigerant will evaporate, this suction line valve will control the temperature of the coil to which the suction line is attached, even though the suction pressure of the compressor is considerably below the coil pressure. The controlled coil or coils such as explained above should not constitute more than 40 per cent of the total load of a system. If the controlled coil is too large, erratic cycling will result. (See surge tanks, Par. 19-44). If the controlled load amounts to more than 40 per cent seperate condensing units should be used. There are two general types of two-temperature valves:

1. Pressure operated
   a. Metering
   b. Snap-action
2. Temperature operated
   a. Vapor pressure
   b. Thermostat and Solenoid

19-39. METERING TYPE TWO TEMPERATURE VALVE

The metering type, two-temperature valve (the first one developed) acts more as a throttling device than as a shut-off valve. It opens and closes when the pressure varies only a fraction of a pound, having no differential. This control is very popular in an ice cream cabinet and a soda fountain installation. The needle may be better termed a plunger because the valve openings must be made large enough not to offer much restriction to the gas flow. Many



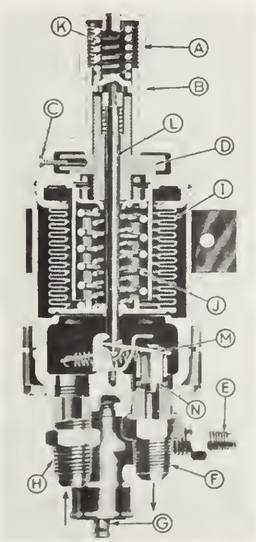
19-49. A snap-action, two-temperature valve. (Fedders Mfg. Co.)

of these metering controls have a very small adjustment range, being especially designed to maintain beverage temperature pressures. The parts are heavily cadmium plated because the valve is often located in damp places. It must not corrode, Fig. 19-48.

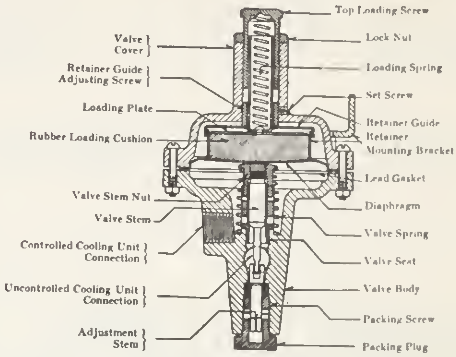
Most of these valves are equipped with a gauge opening to permit the service man to adjust and check the warmer coil pressure.

19-40. SNAP ACTION TYPE TWO TEMPERATURE VALVE

The snap-action type is such that, when the valve closes, a decided rise in pressure is made in the warm coil before the valve will open again. One important function of the snap-action pressure operated valve is that it establishes a definite cut-in pressure and therefore temperature. It is used where one would like to defrost the coil on each cycle, Fig. 19-49. The differential construction is the typical toggle arrangement which is in motor controls and permits both a range and a differential adjustment for the back pressures of the warmest coil. This control is used more with equal temperature coils, but with coils of unequal capacity, although it may be used in place of metering type valves, Fig. 19-50. An example of such an installation would be a multiple system cooling a walk-in cooler and a display case. The two-temperature valve should be located on the suction line to the display case. Another type of snap-action, two-temperature valve is the Barostat which uses the principle of a snap-action diaphragm, Fig. 19-51.



19-50. Snap-action, two temperature valve. A. Cut-in differential adjusting screw; B. Lock nut; C. Range adjustment lock screw; D. Range adjustment nut; E. Gauge connection; F. Outlet; G. Gauge valve stem; H. Inlet; I. Bellows; J. Spring; K. Differential spring; L. Actuating rod; M. Toggle; N. Valve.
(Frigidaire Div., General Motors Corp.)



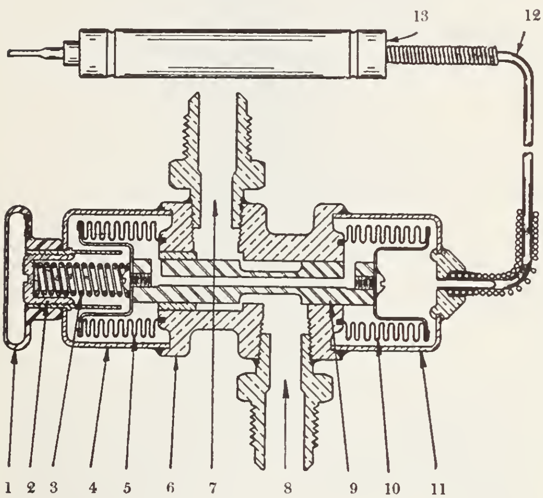
19-51. A diaphragm type, two-temperature snap-action valve.
(Barostat Co.)

19-41. THERMOSTATIC TYPE TWO TEMPERATURE VALVE

Another type of two-temperature valve has a temperature control and is built very much like a thermostatic expansion valve. Its operation is similar in that it operates from the temperature of the coil. It has a capillary tube and a power bulb similar to the thermostatic expansion valve, along with a bellows arrangement to utilize the different pressures created in the power bulb.

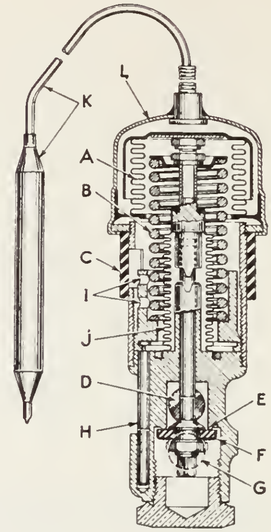
When the coil which this particular two-temperature valve controls becomes cool enough, the power bulb in cooling off also lowers the pressure in the bellows, thus operating the valve plunger and shutting off the valve, Fig. 19-52. This prevents the pressure from becoming any lower in the coil to which this valve is attached, thereby controlling the minimum temperatures of the coil.

As the coil warms up, the power bulb also warms up and the increase



19-52. A thermostatic type, two-temperature valve. A. Bellows case cap; 2. Adjusting screw; 3. Adjusting spring; 4. Bellows case; 5. Adjusting bellows; 6. Body; 7. Outlet or inlet; 8. Inlet or outlet; 9. Control rod; 10. Control bellows; 11. Bellows case; 12. Control line; 13. Control bulb.
(Kelvinator Div., American Motors Corp.)

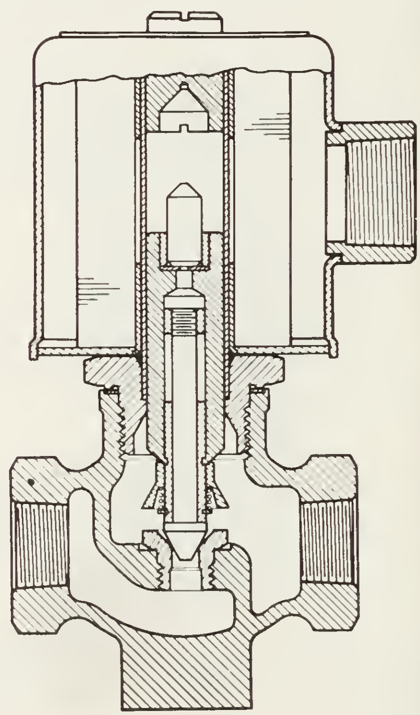
in pressure is transmitted to the bellows. The valve is then opened permitting the compressor to draw vaporized refrigerant from that coil again. This latter type of valve is always located on the warmest coil as are the two previous types, Fig. 19-53.



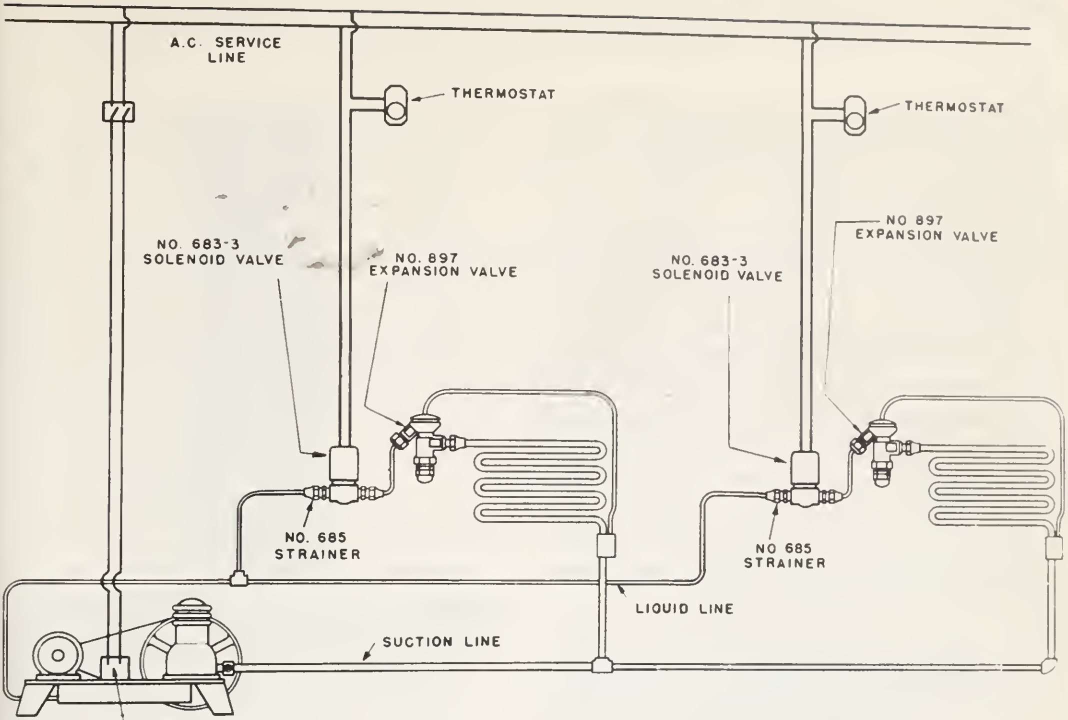
19-53. Thermostatic two-temperature valve. A. Bellows; B. Spring; C. Rubber sleeve; D. Inlet connection; E. Stationary seat; F. Movable seat; G. Outlet connection; H. Indicating pin; I. Adjustment holes; J. Bellows; K. Thermal bulb; L. Valve cap.
(Frigidaire Div., General Motors Corp.)

19-42. SOLENOID VALVE THERMOSTAT COMBINATION, TWO TEMPERATURE TYPE

A fourth way to obtain various fix-



19-54. A diagram of solenoid valve.
(Detroit Controls Corp.)



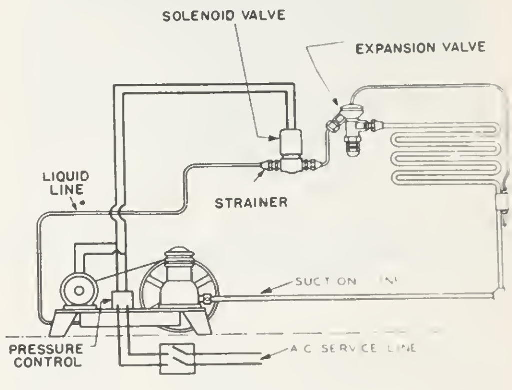
19-55. Installation of solenoid valves. (Detroit Controls Corp.)

ture temperatures in a multiple installation is to use a thermostat connected in series with a solenoid valve, Fig. 19-54.

The solenoid shut-off valve is usually located in the liquid line, Fig. 19-55. Some systems have the solenoid valve in the suction line to prevent removing the refrigerant from the cooling coil. The thermostat is operated by the fixture temperature. When the fixture reaches the correct temperature, the thermostat opens and the electric solenoid loses its magnetism and the valve closes. No more refrigerant is fed to the coil and the cabinet will gradually warm up until the thermostat points close, the solenoid valve opens, and the refrigeration starts again.

This system controls the refrigeration based on fixture temperature, the condensing is controlled by a pressure control, and the motor will stop only when all the fixtures are cooled.

Another application of a solenoid valve is to use it to stop flooding the low pressure side during the off cycle. This solenoid is electrically connected in parallel with the pressure motor control, Fig. 19-56.



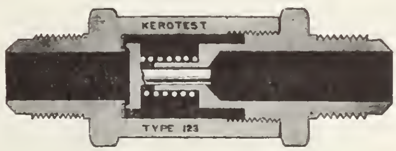
19-56. A solenoid valve located in the liquid line and controlled by the pressure motor control. (Detroit Controls Corp.)

19-43. CHECK VALVES

Many multiple installations are made in which one condensing unit is

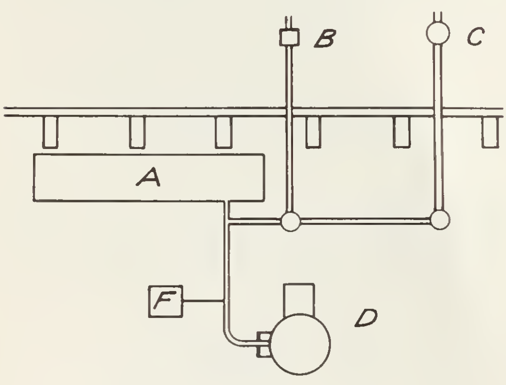
connected to several coils all of which are at different temperatures. Two temperature valves are used to procure these temperatures. Check valves are sometimes put in the suction line of the coldest coils to eliminate erratic refrigeration.

After the condensing unit has stopped, one of the two-temperature valves may open before the condensing unit turns on, tending to flood the low side with a relatively warm refrigerant gas. This gas will also travel along the suction line of the coldest coil. If it enters this coil it will start condensing, releasing its latent heat. This will make the cold coil defrost or at least warm up somewhat. The check valve when installed in the suction line



19-57. A suction line check valve used in multiple temperature installation.
(Kerotest Mfg. Co.)

of the coldest coil will only allow gas to be drawn from this coil and it will prevent warm gas going into the coil to warm it, Fig. 19-57.



19-58. A surge tank installation. A. Surge tank; B. Check valve; C. Two temperature valve; D. Compressor; F. Motor control.

19-59. A cutaway view of an oil separator. A. Inlet; B. Outlet; C. Oil return tube; D. Oil float; E. Mounting bolt.
(Aminco Refrigeration Products Co.)

This check valve must have a tight valve and the valve must open easily. If the valve is too small or it opens with difficulty, it will act as a throttling device and cause too much pressure drop, tending to cause poor refrigeration in the coldest coil.

19-44. SURGE TANKS

A multiple temperature installation has a tendency to short cycle a pressure controlled condensing unit due to the pressure fluctuations resulting from the opening and closing of the two-temperature valves.

For example, if the two-temperature is closed and the condensing unit cools the lowest temperature coil enough to open the pressure motor control, the condensing unit will stop. But if just after this stopping, the two-temperature valve opens, the low side pressure will rise rapidly and turn on the condensing unit, causing a short cycle. To eliminate this trouble a large cylinder or surge tank may be installed in the main suction line just ahead of the compressor. This surge tank is

made large enough that even though the unit is stopped and a two-temperature valve opens, the low side pressure will not build up and start the unit too frequently due to the capacity of the surge tank to absorb a large gas volume and thereby slow down the pressure changes. The line connected from the bottom of this tank to the compressor will facilitate oil return to the compressor, Fig. 19-58.

19-45. OIL SEPARATORS

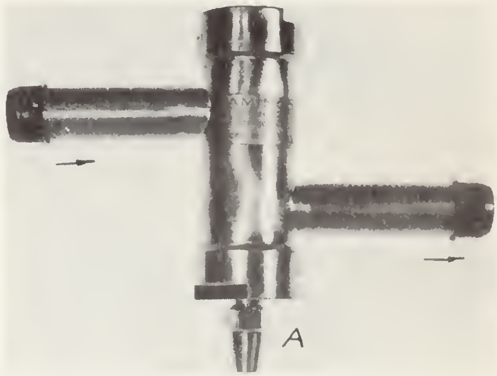
It is very important that the compressor be kept lubricated. Because the compressor does pump a certain amount of oil as it pumps the refrigerant gas, and because there is a possible chance that too much oil may be removed by the compressor, it is important to return the pumped oil back to the compressor as quickly as possible before the compressor friction surfaces are ruined.

All refrigerating systems are more efficient when the oil is kept in the compressor. The capacity of each part of the system is increased by 5 to 15%. It is especially important to keep the oil from circulation in low temperature installations. Figure 19-59 illustrates a cutaway view of an oil separator.

19-60. An oil separator.
(Temprite Products Corp.)

Oil separators are placed between the compressor and the condenser. The oil separator collects the oil pumped over from the compressor and when a certain oil level is reached in the oil separator, a float opens a needle valve allowing the oil to be returned to the crankcase of the compressor. Figure 19-60 illustrates a typical oil separator.

The oil separates from the gas refrigerant because the velocity of the gas slows down as it arrives in the separator. Also the separator is insulated to prevent it acting as a refrigerant condenser.



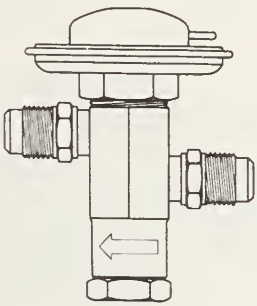
19-61. A suction pressure throttling valve. The arrows indicate the direction of gas flow. The adjusting screw is located under the seal cap A.
(Aminco Refrigeration Products Co.)

19-46. COMPRESSOR LOW SIDE PRESSURE CONTROL VALVES

The starting of a compressor is one of the hardest loads the motor encounters. The inertia of the moving parts and the fact that the crankcase pressure is at a maximum just as the compressor starts, necessitates using motors of excess capacity, and even

then they are usually taxed to their limit at the moment of starting.

A low side pressure control is now being used on some installations which keeps the low side pressures in the crankcase down to a reasonable level, Fig. 19-61. It may be termed a reversed metering, two-temperature valve because it never permits the crankcase pressure to exceed a certain predetermined value and if the suction line pressure tends to exceed this value, the valve shuts the suction line off from the compressor. The body of the valve is usually made of brass,



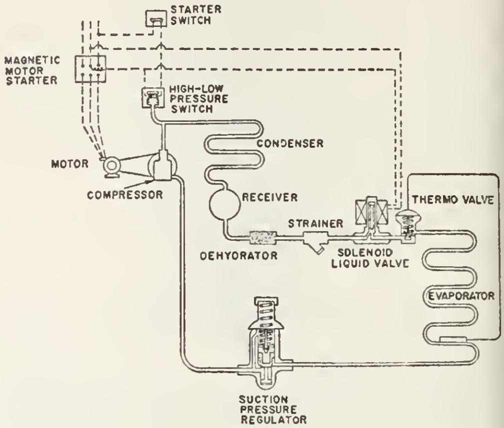
19-62. A non-adjustable compressor low side pressure regulating valve. (Sporlan Valve Co.)

the diaphragm or bellows of phosphor bronze and the needle and seat are made of wear-resisting steel alloy.

These crankcase pressure regulating valves are needed where the compressor has to run too long before the low side pressure drops to a safe pressure. Another type of pressure regulating valve is shown in Fig. 19-62. This valve is non-adjustable and is preset to open at 11 psig for low temperature units or 27 psig for standard applications. The valve is actuated by a pressure difference in the low side and in the refrigerant charge in the cap.

A refrigerating system that uses a pressure operated compressor pressure regulating valve is shown in Fig. 19-63. This system uses three phase power, has a dehydrator, strainer, and a solenoid valve in the liquid line.

Figure 19-64 illustrates a multiple installation cooling, a display case and



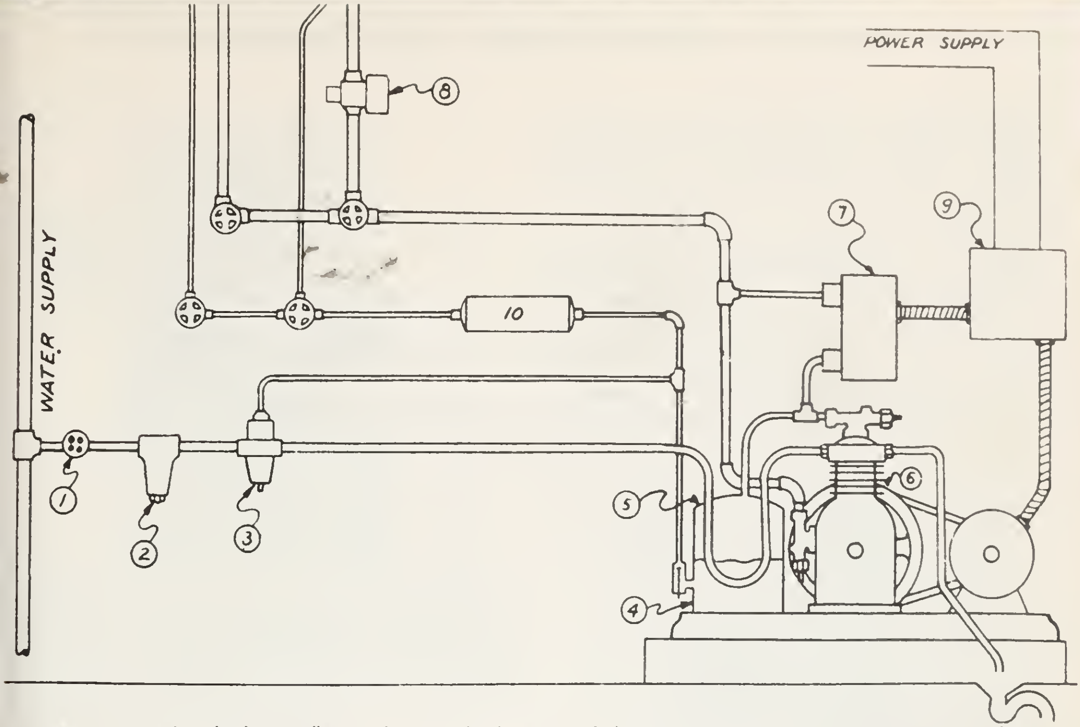
19-63. A refrigerating system showing the relative location of some of the more common refrigerant controls. (Alco Valve Co.)

a frozen foods case. Note the location of the two-temperature valve, the low pressure motor control, the dehydrator, and the water line controls.

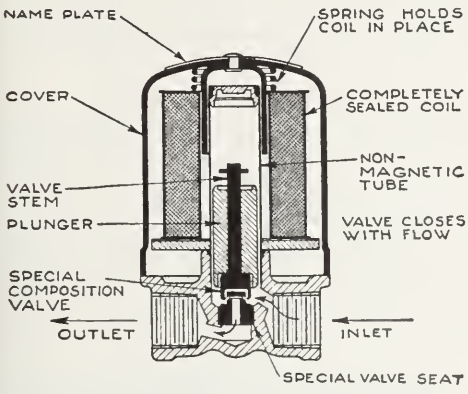
19-47. WATER VALVES

Many commercial units from 1/2 H.P. up use a water-cooled condenser wherever water is available. Due to better heat transfer and the lower condenser temperatures and pressures possible in a water-cooled condenser, the amount of power required to drive the condensing unit will be less than for a corresponding size air-cooled installation. This saving in electrical power compensates to some extent for the cost of the water used.

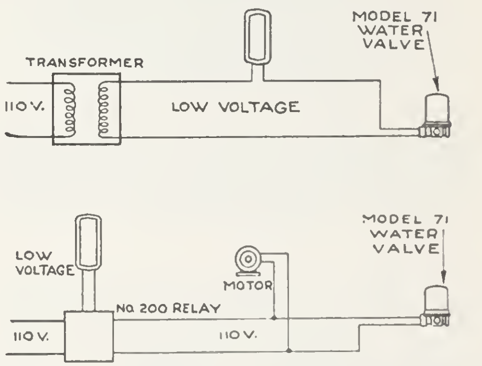
The purpose of the water valve is to turn the water on and off as needed, and also to vary the amount of water as required. The three types of water valves used are the electric type, the pressure type, and the thermostatic type.



19-64. A typical multiple installation showing the location of the important parts. 1. Water shut off valve; 2. Strainer; 3. Water valve; 4. Liquid receiver; 5. Condenser; 6. Compressor; 7. Motor control; 8. Two-temperature valve; 9. Magnetic starter; 10. Dryer.



19-65. An electrically operated water valve. (A-P Controls Corp.)



19-66. An electrically controlled water valve wiring diagram. (A-P Controls Corp.)

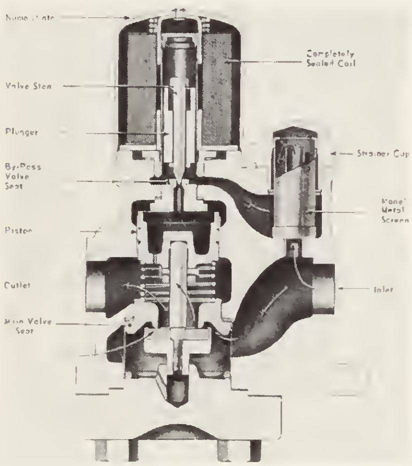
19-48. ELECTRIC WATER VALVE

The original water valves were of the electric type (1920-24). Present day electric water valves are great improvements over those made in the past.

The valve is operated by a solenoid. The principle of operation is: A magnetic coil is connected in parallel with the electric motor; when the electricity is turned on, this magnet creates a magnetic field; a plunger located in the core of the magnet then moves in attempting to minimize the magnetic resistance, Fig. 19-65. The plunger movement opens the water valve, and the water flows through the condensing coils. The valve is located between the water supply and the condensing unit and it is usually mounted on the con-

densing unit. The moment the motor starts, this valve opens, and when the motor is turned off the flow of water is stopped.

These electric water valves, because of their inherent construction, consume a small amount of current while they are in operation. This current varies between six and ten watts, but is compensated for by a saving in water consumed. Fig. 19-66 illustrates

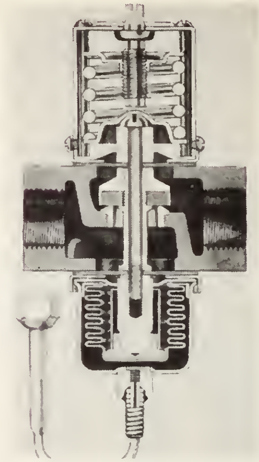


19-67. A by-pass type of electric water valve used on large installations. It should be noted that the solenoid only controls the water by-passed to the large piston which in turn operates the main water valve.
(A-P Controls Corp.)

two typical electric water valve hookups. Both use a low voltage solenoid valve. However, most valves use a 110-volt line.

The body of the valve is brass and is made with both threaded and soldered connections. The plunger is made of a piece of non-corrosive steel. The valve stem is loosely connected to the plunger to permit a shock action to open the valve. Gravity and water pressure close the valve when the power is shut off.

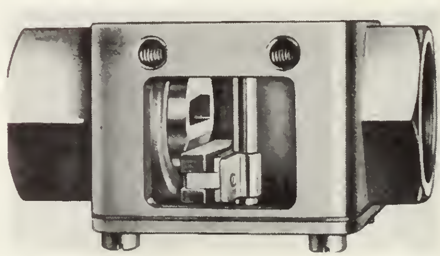
On large units a water valve using the by-pass principle must be used as shown in Fig. 19-67. An advantage in the use of the electrically controlled



19-68. A pressure controlled water valve connected on the high side at the compressor head. The rate of water flow is adjustable by adjusting the spring tension (top) on the valve. The water flows through the valve from right to left.
(Penn Controls, Inc.)

water valve lies in the fact that these valves may be removed or replaced without disturbing the refrigeration system.

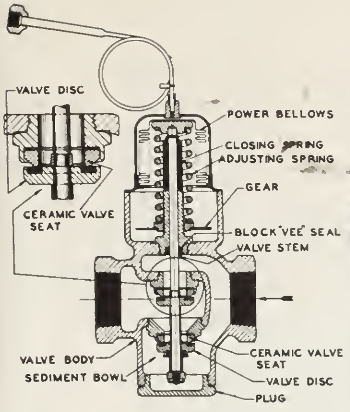
All electrically controlled water valves are so constructed that the pressure of the water tends to keep the valves closed. The valve seats are usually made of brass or bronze and the valve face is of a special rubber composition. The water flow is constant in this type of control.



19-69. A self cleaning type of water valve and seat.
(A-P Controls Corp.)

19-49. PRESSURE WATER VALVE

The pressure operated type of water valve is becoming popular in the com-



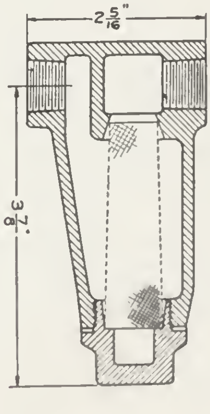
19-70. A large capacity pressure operated water valve. The double valve and seal arrangement tends to balance the force from the water pressure (one valve is opened by the water pressure and one valve is closed by the water pressure).
(A-P Controls Corp.)

mercial refrigeration field. It consists of a bellows attached to the high pressure side of the system, preferably to the cylinder head; this bellows operates a water valve.

In operation: As the pressure rises in the condenser due to the accumulation of the gas, the bellows in the water valves expands and by various mechanisms, depending upon the specific water valve, the valve is opened permitting water to flow into the condenser to cool the compressed gas. It opens the water circuit only when the water is needed, that is, as the pressure rises, Fig. 19-68. It will keep increasing the water flow just as long as there is a tendency for an increase of pressure in the system. These valves are adjusted by the tension of a heavy spring which presses against the bellows. The valves are set to open at certain definite head pressures, depending upon the temperature of the water and the kind of refrigerant used. See Chapter 21. It should be noted that some pressure controlled water valve designs necessitate a regular service operation to remove the valve from the system. Some water valves are made self cleaning to remove dirt particles. The water valve portion of the control may be removed without disturbing the refrigeration system. See Fig. 19-69.

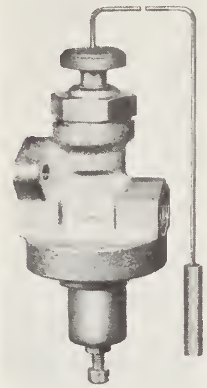
A regulated flow of water is obtained with this valve. As the condensing pressure and temperature increase, the valve opens farther; when the pressures and temperatures drop, the water flow is shut down.

The valves proper are made of a hard rubber composition, Bakelite or fiber, whereas the seat is usually made of copper or brass. The valves are equipped with either a packing gland or a bellows at the point where the water valve actuating stem goes into the water valve body. The packing construction must be adjusted occasionally to keep it from leaking. The bellows, being a sealed mechanism, can only leak if it corrodes through. These valves usually do not depend on the pipe for support, but are provided with a mounting arrangement or flange. The water-in and the water-out connections are clearly labeled and the valves are usually threaded for 3/8 in. standard pipe. Most of the valves are constructed so that the water pressure tends to keep the valve closed. Fig. 19-70 shows a large capacity



19-71. A water line strainer. The opening in the upper left hand corner is the water into the strain connection.
(Kerotest Mfg. Co.)

valve used on 1 in. water lines. This valve has a gear mechanism for adjusting the pressures.



19-72. A thermostatic water valve. The valve will start to open with a bulb temperatureof 120 F. and will be wide open at 125 F. The flow rate is adjustable (bottom screw) from 0 to 50 gallons per hour.
(Detroit Controls Corp.)

Both the electric and pressure type should be equipped with filters; that is, they should have screens in the water supply line to remove any solids from the water, Fig. 19-71.

19-50. THERMOSTATIC WATER VALVE

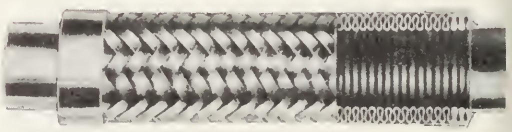
The thermostatic water valve is controlled by the temperature of the exhaust water. The valve proper is identical to the pressure water valve with an addition of a thermostatic element connected to the bellows operating the valve. The element is charged with a volatile liquid. The power bulb is clamped to the compressor discharge line. The pressure created by the volatile liquid in the bulb opens the valve when the discharge line becomes warm and closes the valve as the line cools, Fig. 19-72.

19-51. MANUAL VALVES

Manual servicing valves used on refrigerating machines enable a service man to determine the operating pressures, to charge or discharge a system, or to remove any part of the system without disturbing the other parts. These valves must be of a sturdy construction and must be designed to withstand continual opening and closing without leaking externally or internally. They should be built of the best materials to withstand corrosion and deterioration.

19-52. CONDENSING UNIT MANUAL VALVES

The condensing unit is equipped with servicing valves similar to those of the conventional domestic system, with the exception that these valves are sometimes larger. That is, the valve stems may be 3/8-in. across flats, and the gauge connections may be 1/4-in. pipe instead of 1/8-in. pipe.



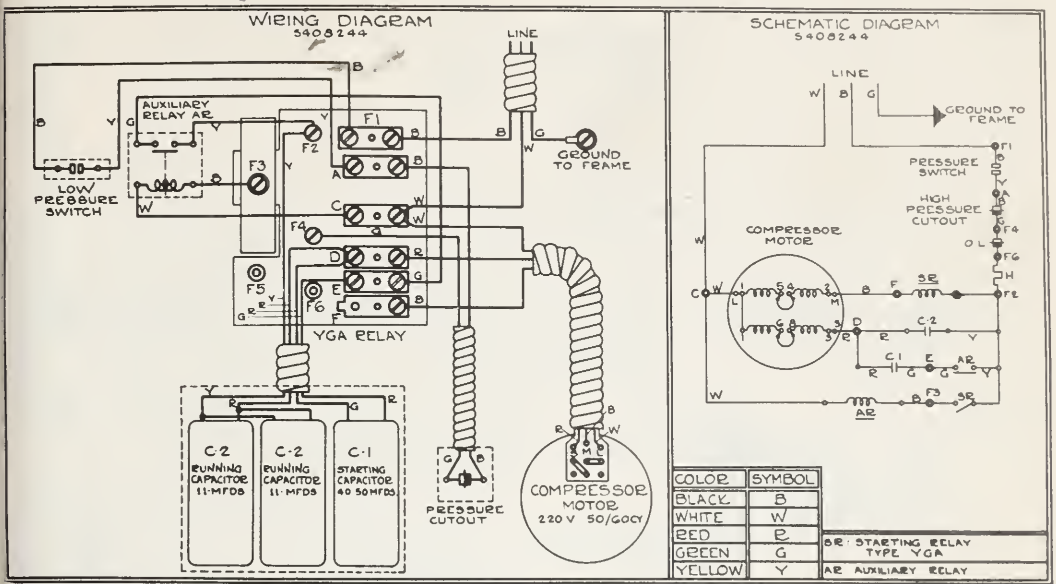
19-73. A vibration absorber. Installed in suction and liquid lines it prevents condenser vibration from traveling into these lines.
(Flexonics Corp.)

This also pertains to the liquid receiver servicing valve, except that some of the units have an extra liquid receiver servicing valve located between the condenser and the liquid receiver.

19-53. MANUAL INSTALLATION VALVES

In addition to the usual service valves, multiple installations are equipped with what are termed hand shut-off valves. These valves are required by law to be so located that they may

be manipulated easily and be readily accessible. They may be classified as riser valves or manifold valves. In multiple installations it is very convenient to run the suction line from the compressor to a drop forged or cast-brass pipe and then to have the individual suction lines for each cooling unit go from this manifold to the coils. Between each of these suction lines and the manifold, and mounted into the manifold, is a hand operated shut-off valve. This permits any one of the suction lines to be closed without interfering with the operation of the others. A similar manifolding device is also provided for the liquid line. Installation procedure usually provides for mounting these valve groupings in a steel box or cabinet or a special valve board.

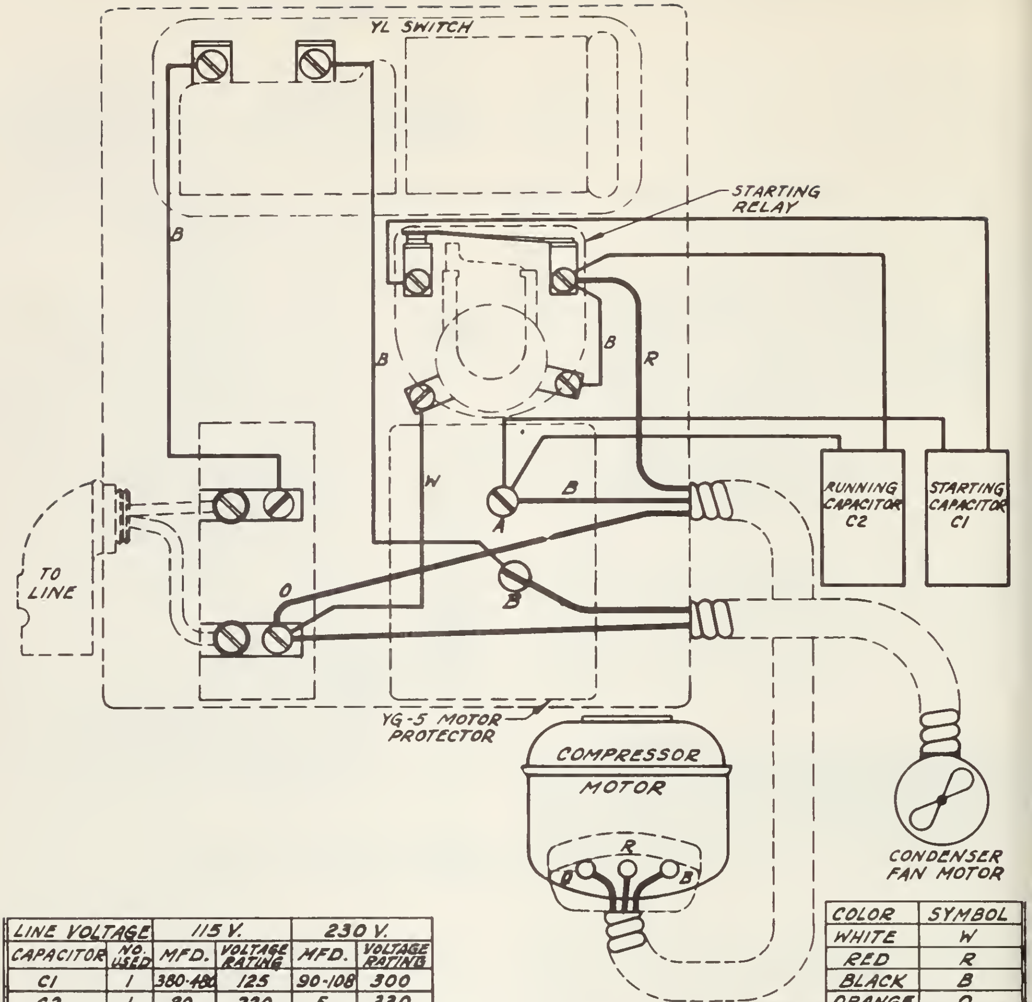


19-74. A wiring diagram of a commercial hermetic system without a condenser fan.
(Frigidaire Div., General Motors Corp.)

19-54. RISER VALVE

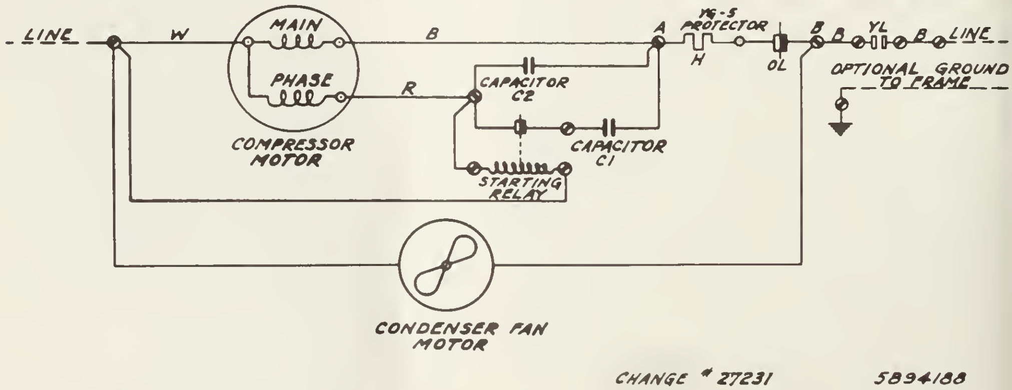
Another type of valve, which is used as a shut-off valve and which is also termed a riser valve, is a hand operated valve with three openings to which refrigerant lines may be connected. Two of these openings are in line with each other on opposite sides of the valve, while the third one is a little closer to the valve wheel and is at right angles to the other two openings. By screwing the hand valve in, the opening at right angles to the other two is closed. This construction permits mounting the valve in either a liquid or suction line, enabling one to connect a second coil to it which may be disconnected at any time from the remainder of the system by screwing the valve all the way in.

All service valves are of the drop forged construction to minimize seepage through the valve. The valve stem may be of either brass or steel, with steel being quite popular. The packing around the valve stem may be asbestos, lead, and graphite, or the valve may be of the packless type. At pres-



LINE VOLTAGE		115 V.		230 V.	
CAPACITOR	NO. USED	MFD.	VOLTAGE RATING	MFD.	VOLTAGE RATING
C1	1	380-480	125	90-108	300
C2	1	20	220	5	330

COLOR	SYMBOL
WHITE	W
RED	R
BLACK	B
ORANGE	O



19-75. A wiring diagram of a commercial hermetic system with a condenser fan.
(Frigidaire Div., General Motors Corp.)

ent the packless type valve, meaning the type which uses a bellows diaphragm as a sealing device rather than a packing, is most popular. Many

of the new valves have self-seating features. This means the valve is easily seated again by tapping the valve stem into the seat. The valve seat is made of a soft lead alloy or Monel metal.

19-55. REFRIGERANT LINES

Hard drawn copper pipe is used to carry the refrigerants around the cycle. This pipe is furnished in iron pipe sizes and the fittings are not interchangeable with tubing sizes. See Chapter 2 for copper pipe sizes. Streamline soldered connections are used to connect the fittings to this pipe.

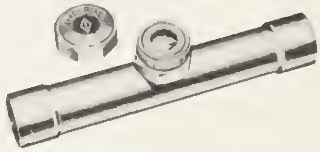
The National Refrigeration Code and local codes all require the hard copper pipe. Soft copper tubing is permissible at the condensing unit end of the lines and also in the fixtures but even these short lengths are eliminated wherever possible.

To prevent any condensing unit vibrations traveling into the lines, vibration absorbers are installed in the suction and the liquid lines near the condensing unit, Figure 19-73.

Because the appearance of an installation is important, the piping should be put in as neatly as possible.

19-56. SIGHT GLASSES

It is almost universal practice to install a sight glass in liquid lines of commercial installations. Most sight glasses are installed in a vertical flow tube. However, the sight glass shown in Fig. 19-76 can be installed in a horizontal line as it has an internal device which reads "Full" when there is sufficient refrigerant, and shows no reading when there is no liquid in the line. This sight glass has long extensions which permit soldering the joints without injury to the sight glass.

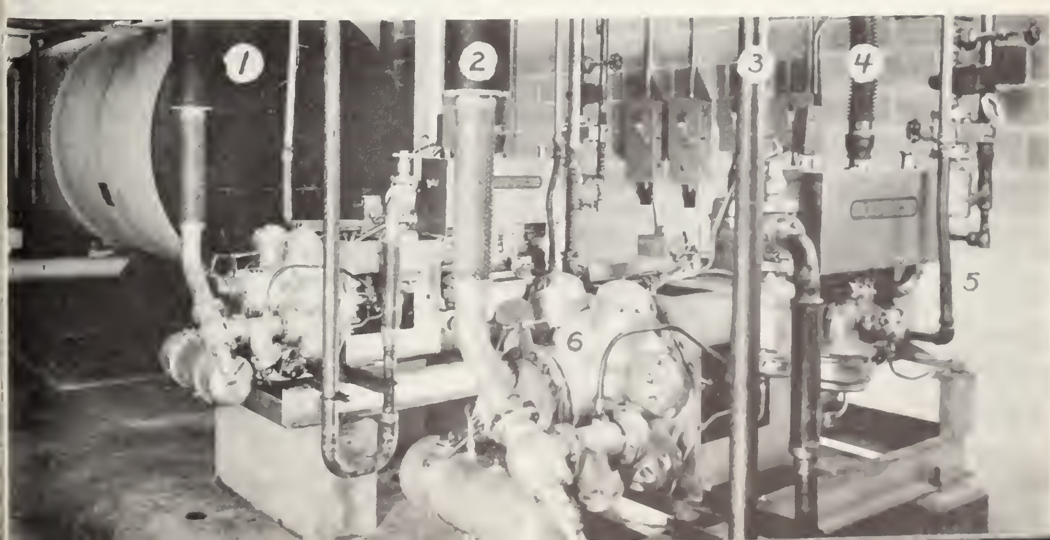


19-76. A sight glass designed for soldered or brazed connections.
(Imperial Brass Mfg. Co.)

19-57. NATURAL GAS ENGINE DRIVEN SYSTEMS

Natural gas engines may be used to drive refrigerating machines. The ad-

19-77. Two natural gas driven refrigerating units. 1. Water Chiller, 2. Suction lines, 3. Discharge line, 4. Engine exhaust line, 5. Natural gas engine, 6. Seven cylinder radial refrigerant compressor.
(Ready-Power Co.)



vantages are a variable compressor speed to produce flexible capacity and a low operating cost. The units are available in 4 to 75 ton capacities. Fig. 19-77, shows an installation of two of these units. Engine-compressor units of 1 to 5 tons capacity for use on mobile units, and for air conditioning, use gasoline or propane as a fuel.

19-58. REVIEW QUESTIONS

1. What are the advantages of the non-frosting cooling coils?
2. Why must high pressure motor cut-outs be used with water-cooled condensing units?
3. Where are the intake valves of a compressor usually located?
4. Why is it advisable to connect the high pressure motor cut-out into the cylinder head of the compressor?
5. Name the three types of water valves.
6. Name the various two-temperature valves.
7. What are the advantages of water-cooled condensers? Air-cooled condensers?
8. What are the advantages claimed for forced circulation cooling coils?
9. Why is the pressure type motor control usually used in multiple installations?
10. In multiple installations which use two-temperature valves, where should the check valves be placed?
11. What per cent of a refrigeration load may be placed on a coil controlled by a two-temperature valve?
12. Why does an evaporative condenser save 85% of the water consumption?
13. Are liquid receivers equipped with safety devices?
14. What is inside the inner tube of a tube within a tube condenser?
15. How is cast aluminum used in a liquid cooling coil?
16. What is the contra-flow principle in water cooled condensers?
17. Why are combination air cooled and water cooled condensers used?
18. Why must cooling coils be cleaned even though they are automatically defrosted?
19. How is water used to defrost a system?
20. Why must the drain pan and the drain pipe be heated during defrosting cycles?
21. What is the purpose of the check valve in the reverse cycle defrost system?
22. Why is a motor starter necessary?
23. Why is an oil separator insulated?
24. Why do some hot gas defrost systems reheat refrigerant before it returns to compressor?
25. Which type water valve will not vary the water flow as the refrigeration load changes?
26. Why is a float valve used with an evaporative condenser?
27. Does a flash cooler for a walk-in meat cabinet need an automatic defrost system? Why?
28. What is the purpose of a surge tank?
29. What is a sweet water bath?
30. Where are vibration dampers installed and why are they needed?

Chapter 20

COMMERCIAL REFRIGERATION INSTALLATION AND SERVICING

Commercial refrigeration installations vary considerably. The following types of installations are used:

1. Self contained units.
   a. Hermetic units.
   b. Conventional units.
2. Remote condensing unit installations.
   a. Single cabinet.
   b. Multiple cabinet.

The size of the installation may vary from 1/20 H.P. contained units to 15 H.P. units for large cabinets.

The size of the larger units is such that the assembly work of the complete system must be performed on the premises.

The small units of the package type construction do not necessitate this complicated arrangement; instructions for installing and maintaining them will be found to be very similar to those in Chapter 9 for domestic machines.

For example, a self-contained water cooler for an office necessitates only three connections. Electricity is obtained by means of a plugged in connection, and a plumber will be able to connect the water and attach the drain to the system.

Multiple installations must be installed to handle the refrigeration load efficiently and must be set up to minimize the chances of accidents. All installations should be made with permanency and neatness as the two main objectives. Many cities have laws and codes designating how and where certain refrigerating apparatus may be installed. See Paragraph 29-7 for the National Refrigeration Code. Also most refrigerating companies have rules directing how their equipment should be installed. Previous to the time cities and the manufacturers systemized their procedures, many installations were made with the workman's own ideas incorporated in the job.

Many small cities and rural communities are not restricted by code, and installations are usually put in at a minimum cost. One must, therefore, consider two types of installations:

1. The non-code installation.
2. The code installation.

A good practice to follow is to install all units according to the National code.

The servicing of commercial installations in some respects is similar to that of the domestic unit. However, the use of multiple cooling coils on a single compressor, and the use of the thermostatic expansion valve, plus the rather universal application of water-cooled condensing units, necessitates a rather detailed study of how these commercial units may be serviced.

The troubles encountered come under various headings such as, no refrigeration, continuous running, a high electric bill, poor refrigerating tem-

peratures, frosted suction lines, etc.

Servicing information in this chapter deals mainly with the multiple systems, what goes wrong in them, and how to repair them. Much of the servicing is similar to that followed in domestic practice and the material in Chapter 11 may be used to a considerable extent. The tools listed in Chapters 2 and 12 are usable for commercial servicing.

20-1. NON-CODE MULTIPLE INSTALLATIONS

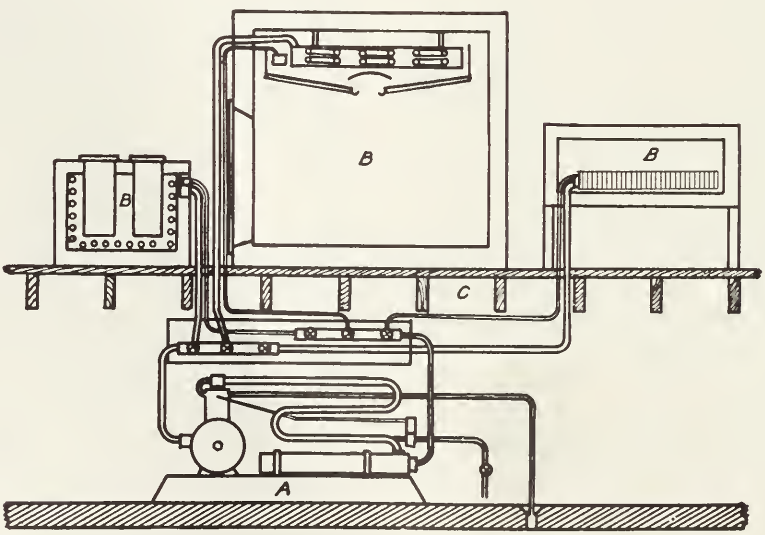
A definite procedure of routing should be closely adhered to when assembling a multiple system in order to safeguard against any faults in assembly, and to eliminate careless procedures which refrigeration service departments claim produce more than 90 per cent of the servicing difficulties. Assuming that the problem has been completely solved from the heat load angle (Chapter 21), and that the units are well proportioned and of such a size that they will efficiently handle the load, the proper installation must be made in a way to take full advantage of these factors. In a non-code installation, the tubing, safety valves, and protective devices should be incorporated in the installation with operating efficiency, permanency, safety, and good will as commanding factors.

20-2. INSTALLING CONDENSING UNIT

The first problem to be solved is the location of the condensing unit in respect to the cabinet or cabinets, Fig. 20-1. It is only natural that this location should be as close to the various cabinets as possible, i.e., a central location.

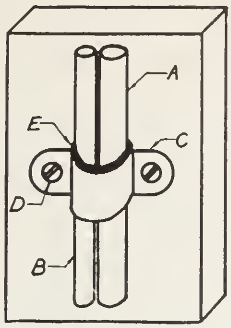
The installation should be done in the following order.

1. Put the cabinets in their proper place.
2. Locate the place for the condensing unit and install it.
3. Install the cooling coils.
4. Install the valves and controls.
5. Install the tubing.
6. Check for leaks.
7. Dehydrate the installation.



20-1. A typical non-code installation. A. Condensing unit; B. Cabinets; C. Floor line.

8. Start the unit.
9. Check the operation of the unit and obtain 24 hour temperature and pressure records of the units operation.



20-2. A method of fastening the tubing to the wall. A. Suction line; B. Liquid line; C. Clamp; D. Wood screw; E. Friction tape.

It is recommended that the condensing unit be put in the basement or in an adjacent room to the one in which the cabinet is located. Avoid putting the condensing unit where it will be exposed to very low or freezing temperatures. Locating the condensing units in the same room with the counters and boxes is often somewhat disturbing because of the noise produced.

The location of the condensing unit must also be governed by the source of electrical supply, water supply, and water drainage. The plumbing and electrical connections should be done by licensed contractors in those fields. The refrigeration contractor can easily sub-contract these segments of the installation. The proportioning of the cost as to the running of the electrical lines and the refrigerant tubing is a local problem, but most refrigeration service men prefer to minimize the electrical work and extend the refrigeration lines, if necessary, because it is more in their own field. This idea is basically uneconomical, because of the reduction in efficiency of the condensing unit when the tubing is run a long distance.

The condensing unit should be mounted on a cement base, if possible, and hold-down bolts are recommended to keep the unit stationary. The unit should be mounted level. At least two of the condensing unit legs should be adjustable to enable the unit to be mounted level and still firmly mounted on all supports. Commercial condensing units are usually provided with a base which usually permits mounting the condensing unit on the floor. However, when the floor is moist or when the floor is dustier than normal, a stand should be constructed of wood, steel, or cement to enable mounting the unit 20 to 40 inches above the floor. A flimsy base will magnify any vibrations or sounds and should not be used. After the locations of the various units are determined, a sketch or drawing of the entire installation should be made to eliminate mistakes in the estimate of supplies, parts, etc. One should be familiar with the symbols in these drawings.

The condensing unit should be placed in an accessible place. Do not put it under stairways or in closets. Remember that if it is an air cooled unit it must have considerable air volume for its cooling air.

Protect the condensing unit from heavy objects or falling objects by putting a heavy wire cage around it and over it. A neat installation requires a valve and accessory board to be installed on the wall just above the condensing unit. This board should support the valves, the dryer, the two-temperature valves, the electric boxes, and instruction cards for service work.

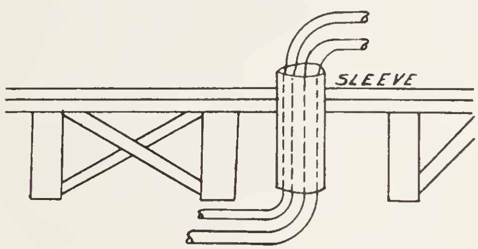
20-3. INSTALLING COOLING COILS

Cooling coils should be carefully mounted and firmly fastened. The cooling coils are usually fastened to the ceiling of the cabinet if it is either a grocery, a florist walk-in cooler, or the

like. The coil can be correctly mounted by using a plumb line to locate the holder positions. Also the coil should not be held awkwardly while the hanger positions are marked in the ceiling or wall. A cardboard template is also a useful means for locating mounting devices.

Display counter coils are usually supported from underneath the coil by stands. These stands or brackets should be provided with an adjustment, to help level the coils in all directions. These hangers are usually made of galvanized strap iron 1/8-in. x 3/4-in., or of copper.

The hanger may be attached to the ceiling of the cabinet in one of three ways. It may be bolted directly through the cabinet ceiling with galvanized or tin plated carriage bolts, or the hanger may be fastened to a sheet by means of



20-3. A sleeve to protect tubing as it goes through wall or floors.

cap screws (both of these being plated to prevent rusting), and the plate in turn is fastened to the ceiling of the cabinet by brass wood screws. The third method is to fasten the bracket directly to the ceiling by means of wood screws. The second method is considered the best, although it is a little difficult in some cases. If none of these is workable for the particular installation, horizontal steel piping fastened to the walls of the cabinet may be used as supports for the coils, or the coils may be supported from underneath by a stand which is fastened to the baffles in the cabinet. These later devices make it rather difficult to mount the coil in a level position and to keep it in a firm position. Regardless of the devices used to mount the coil, they should be rechecked after being put in, to insure that they are level.

20-4. INSTALLING TUBING

The tubing in non-code installations is usually run along the walls and ceiling; it is supported only at intervals frequent enough to keep the tubing straight and firmly in place. Special clamps are manufactured as tubing fasteners, but a galvanized conduit clamp of the 1/2-in. size is sufficient for most situations, Fig. 20-2. The tubing should be insulated from these clamps or protected from them by means of a short wrapping of friction tape to prevent chafing.

Where the tubing is run through the floor or wall, it should be adequately protected by means of short runs of conduit, or flexible metal tubing (Greenfield), and the ends sealed up with some sealing compound, otherwise chafing of the tubing and corresponding troubles are likely to result, Fig. 20-3. The tubing in all cases should be run horizontally and vertically with neat looking bends of as perfect radius as possible.

The liquid line presents no difficulties as to its slant and position, but one must always install the suction lines so the tubing will drain into the compressor. Any low spots in the suction lines will act as accumulators of return oil, and will eventually form a liquid slug in the tubing; when this is carried to the compressor it will cause some disturbance in the crankcase, resulting in temporary oil pumping. If the tubing must slant upward on returning from the cooling coils to the condensing unit, the construction should be made to permit a steady downward

slant of the tubing to a certain point at which a U-bend is located. The U-bend will act as an oil trap, functioning as the low spots mentioned above, insuring a positive return of oil to the compressor. This is poor practice, however, and should only be used as a last resort.

The tubing should never be run near sources of heat, such as hot water lines, steam lines, near furnaces, etc. Such sources of heat will cause poor refrigeration or at least will reduce the efficiency of operation.

As previously stated in the text, copper tubing comes in coils usually of 50-foot lengths, and the tubing is dehydrated and then sealed at the ends by the manufacturer. In the average commercial installation 1/4-in. tubing is used for the liquid line and 1/2-in. tubing is used for the suction line. It is only in cases such as large installations and sizable air-conditioning systems that a larger, liquid-line tubing is required. Only the very largest commercial installations use a larger suction line tubing than 1/2-inch, although practically all the air-conditioning installations use larger tubing.

This tubing during the period of installation should be kept as clean as possible. The tubing should never be put aside with the ends open. If possible all tubing should be put in place before being unsealed. The tubing should be sealed if it is not to be used for a period of five minutes or more. See Paragraph 2-3 for tube sealing instructions. The most practical method of installing this tubing is to uncoil 10 feet of it at a time by unrolling the coil along the floor and then run it up through the floor openings from underneath, gradually working the tubing into place.

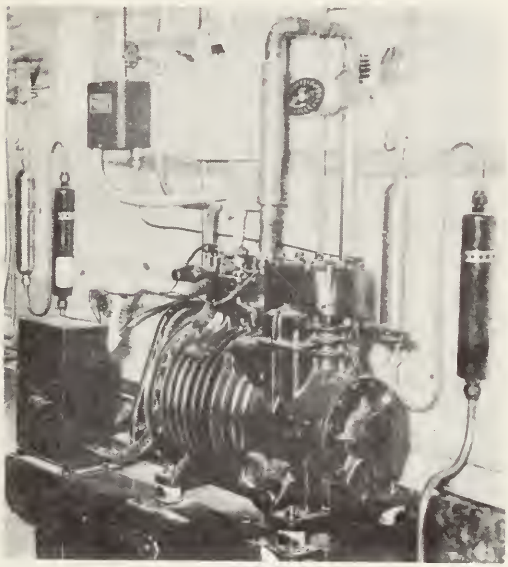
One will not have any difficulty in installing the 1/4-in. tubing, but 1/2-in. tubing must be rather carefully handled to prevent buckling at the bends. Tube benders of all sorts are available for bending the tubing and should be used.

In a non-code installation where the individual suction lines and liquid lines run into the main lines, T-connections may be used and the valves for shutting off the individual coils may be located near the coil itself. Valves, dryers, or other heavy objects should not be supported by the tubing. These articles should be mounted on the wall or some other support. These connections may be of the 45 degree S.A.E. flare type, or of streamline soldered fitting construction. The most serviceable installation may be made with the use of streamline type flange fittings inside the cabinets. One has the choice of streamline fittings or flared connections outside the cabinet on the tubing runs between the cabinet and the condensing unit. Considerable trouble can be avoided if the flares are made as good as possible and that the tubing does not have any "spring away" tendency at the flare. Soldered conditions are made easily if proper procedures are followed. See Chapter 2.

Whenever tubing is installed it should be immediately sealed after the flare or streamline connections are made to keep it as clean as possible and the tubing should be attached permenantly to the supports along which it runs.

Always run the tubing in such a manner that the construction of the support protects the tubing from accidents. That is, do not place it in such a position that a person carrying an object through a doorway or around a corner is liable to catch the tubing and strain it excessively, or do not put it in such a place that it is open to abuse from the handling of articles in that room. Do not put any loops or unsupported bends in the tubing except at the condensing unit.

At the condensing unit, one should always install a dryer in the liquid line, a vibration damper or soft tubing with at least one horizontal loop, and a sight glass in the liquid line, Figure 20-4.



20-4. A condensing unit with tubing installed. Note the vibration dampers, etc.
(Johnston Refrigeration Service)

20-5. REMOVING AIR

After the tubing is installed the following should be done to prepare the unit for operation.

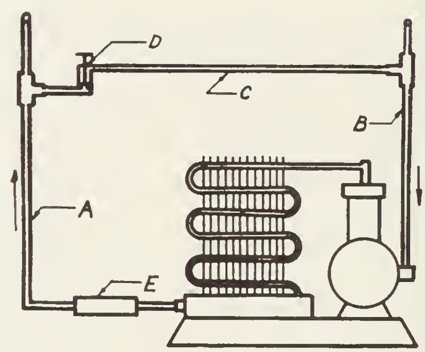
Air may be removed by forcing it out of the lines using refrigerant or some clean non-condensable gas(CO_2, N_2 or Argon). The air may also be removed by pumping a vacuum using either the condensing unit compressor (not recommended) or a separate vacuum pump. The liquid lines must be free of air before the unit can be operated. The liquid lines should be cleaned before they are connected to the thermostatic expansion valve and the cooling coil.

A method used by many installation men is to connect a by-pass line from the liquid line to the suction line near the compressor, Fig. 20-5. This line is controlled by a one-way hand valve and may be used to pump a vacuum on the liquid line. In detail, the compressor pumps a vacuum on the suction lines first; then with all the liquid line valves closed, the by-pass valve is opened allowing the vacuum to be pumped on the liquid lines also. Purging the lines may also be performed when one uses this method. The following paragraphs will explain some further uses for this by-pass valve. Do not put a dryer in the system until most of the air has been removed. Use a short length of tubing in place of the dryer.

20-6. EVACUATING SUCTION LINE

To remove the air from the suction lines the usual procedure is to pump the air out of the lines by using the compressor, or a vacuum pump.

To use the compressor proceed as follows: One must put a compound



20-5. A by-pass line for emptying and evacuating liquid lines. A. Liquid line; B. Suction line; C. By-pass line; D. Shut-off valve; E. Strainer.

gauge on the compressor suction service valve or install a gauge manifold and remove the refrigerant from the crankcase of the compressor by drawing a 20-in. vacuum or more. Be careful of oil pumping. Then, install a purging line into the gauge opening of the

discharge service valve. This purging line must be equipped with a hand shut-off valve. Run this line out-of-doors into a bucket. Turn the discharge service valve all the way in, shutting off the condenser opening. Now turn the suction service valve almost all the way out and pump a vacuum on the suction lines. The air being removed will be discharged out the purging line. This line may be run either outdoors or into a receptacle. Avoid purging it into the room where the condensing unit is located as gases of any kind are harmful to the people in the room. After creating as high a vacuum as possible with the compressor, which means that 70 to 75 per cent of the air in the suction line has been removed, the extreme refrigerant valve may be cracked very slightly. This will permit a very small quantity of the refrigerant to come down the suction line; when this has been pumped from the system, the amount of air left in the suction line will be negligible.

20-7. TESTING FOR LEAKS

After these two lines have been cleansed of air, the unit is ready to operate, but it should be very carefully checked for leaks first. The best way to locate leaks in any system is to build up a pressure in all parts of the system using a non-condensable dry gas (CO_2, Nitrogen or Argon). In case a low pressure refrigerant is used, or if the local code specifies a pressure test above the refrigerant's vapor pressure some other gas may be used for testing. Carbon dioxide or nitrogen are satisfactory. Caution: Never use oxygen or any flammable gas for this purpose. This testing should include the liquid line, suction line and all other parts installed by the installation man except the condensing unit of this particular installation. After building up a pressure, the various means for testing for leaks should be used and checked over very carefully. See Paragraph 11-37. A small leak is very hard to find, and unless a very careful leak checking routine is followed, will eventually result in considerable trouble. If the pressure gauges show no drop in pressure after an hour or more, one should raise the test pressure and test again. Do not exceed the pressures as prescribed by the National Code. The cost of the refrigerant to be replaced and the hazards to food and human comfort from lack of refrigerant makes checking for leaks a paramount requirement. Figure 20-6 shows the equipment used by most service men for checking Halide refrigerant leaks.

20-6. An acetylene cylinder a pressure regulator, a long hose, and a halide refrigerant leak detector torch. Linde Air Products Co.)

20-8. CHECKING UNIT BEFORE STARTING

If the motor control has not been already adjusted for the installation, this should be done before the system is set in operation. The settings of the motor controls will vary with the demands of the cabinets and with the various kinds of refrigerant used. Be sure the water is turned on in case

it is a water-cooled condensing unit, and that the fuses in the electric curcuit are the right size.

20-9. STARTING UNIT (LOW SIDE FLOAT SYSTEM)

Enough low side float systems are still in service to warrant an explanation of how to start them. Open all the liquid line and liquid receiver valves. Start the compressor. When starting a completely warm installation of this kind if the cooling coil low side pressure is permitted to go into the crankcase of the compressor unreduced, an excessive load will be imposed upon the compressor and motor and serious harm is likely to result. Since the compressor pulls down the low side pressure very rapidly, the following procedure is believed to be the best. After starting the unit, open the suction line valve on the various cooling coils, one at a time at 10 minute to 15 minute intervals and open each valve very slowly. It should take at least two minutes to open each of these suction line valves two turns. This procedure gives the compressor time to reduce the high pressure on the low side to close to the normal level.

After all the cooling coils have been opened and everything is running normally, the service man should stay on the premises for at least an hour checking the operation. He should return within 24 hours to determine how the system is performing. The checking of the system should include the high and low side pressures, vibration of the unit, the amount of water flow in case of a water-cooled system, and the temperatures of the suction lines at the cooling coils to find out if they are flooding back due to out-of-calibration, or a leaky needle. It is recommended that an installation of this kind be checked with a 24-hour thermograph after the unit has settled down to a routine cycle.

20-10. REMOVING AIR (DRY SYSTEM)

After the tubing has been installed and connected with the thermostatic expansion valve system, the service man should evacuate the system and remove the air from the newly installed parts in a manner similar to that described in Paragraphs 20-5 and 20-6.

Most dry coils are fitted with sealing caps over the tubing ends to prevent moisture and dirt from entering them during shipment and installation, but these caps are not always air-tight. This means that the coils should be evacuated just as thoroughly as the liquid and suction lines. The best procedure for cleaning this part of the system is to evacuate it, using a method very similar to that described for removing air from the low side float coil installation.

This procedure as stated before is the method whereby air is pumped out of the lines and the coils into the open air, and the liquid receiver service valve is then cracked. The only valve to be kept closed during this procedure is the liquid receiver service valve. All the others are to be as far open as possible, permitting the evacuation to work on all parts of the system. After all the air has been removed and the unit purged, the service man should test for leaks using a pressure throughout the system and then a high pressure. The leaks should be carefully looked for because, as previously explained, this is one of the most important steps in an installation of any kind.

20-11. STARTING A DRY SYSTEM

Thermostatic expansion valves when they are warm are completely open. To start the system with the full

load of all the coils on it, the compressor will be overloaded, as in the low side float installation. Therefore, all liquid line valves should be closed and the condensing unit started. The liquid line manifold valves may then be opened one at a time, requiring two minutes to turn the valves two revolutions. It is a very important precaution in refrigeration never to overload the compressor even for very short intervals. After one coil has been opened and after a 15-minute interval of operation, the coil has a chance to cool down somewhat, tending to make the expansion valve throttle off the refrigerant. This gives the compressor a chance to gradually reduce its load. The remainder of the coils may then be brought into service in the same way.

The service man, after starting the unit, should check the high and low side pressures, the amount of waterflow in case it is a water-cooled system, and the operation of each individual expansion valve. Also determine if the adjustment is correct for each coil; that is, frost or sweating on the suction line will indicate whether or not the expansion valve is opened too far or not far enough. Another very important procedure or routine to be followed at this time is to determine whether or not the system has enough refrigerant. This should be done as described in Paragraph 20-36.

20-12. CODE INSTALLATIONS

Many localities now have very definite rules and regulations pertaining to the installation of refrigerating equipment of all kinds. The code covers the various classes, but pertains mostly to industrial and commercial refrigeration. Domestic units are not usually included in code regulations because the manufacturers of these units cover in detail the necessary requirements. In commercial installations, where the units are assembled on the premises, there are certain requirements that must be adhered to in order to insure a uniformity of performance, and to make the installation as satisfactory and safe as possible.

Installation codes also protect the purchaser from careless installations made by untrained persons or made in such a way as to be maliciously criminal. Most cities have a code of this nature and some of the high points of all codes are the following: Only licensed refrigeration contractors may install commercial equipment, a permit must be obtained for each installation, each installation must be inspected, the lines must be labeled as to refrigerant, certain safety devices must be installed in the system, the condensing unit must be installed in a safe place, the electrical and plumbing work must be done by licensed electricians and plumbers respectively, the system must be tested under certain pressures on both the high and low side, and it must be free from leaks. See Paragraph 29-7 for the recommended National Refrigeration Code.

The National Code and Local Codes are accumulations of thousands of experiences with installations. These codes are based on the premise of safety for the installer, the owner, the user, and the public. Experience has shown that code installations give better service, are easier to maintain and in the end result, are more economical.

The code recommendations vary as to the amount of refrigerant that may be placed in the system (human safety). The more refrigerant in a system, the greater forces that can be created under high temperatures and the more air the escaped gas will displace and therefore the more people it can asphixiate (suffocate).

The code recommendations vary as to the kind of refrigerant. The more

explosive or flammable a refrigerant, the more dangerous it is to people and property. The more toxic (poisonous) a refrigerant is the more dangerous it is to people.

The code recommendations also vary with the type of service in use. For example, one has to be more careful where invalids, handicapped, and restricted persons are concerned. Also, the danger of panic where large groups of people are gathered (public assemblies) must be considered.

A good refrigeration craftsman should be grateful that the time and trouble has been taken to prepare codes that so throughly protect all concerned if carefully obeyed.

20-13. INSTALLING CONDENSING UNIT

In all cases condensing unit must be firmly mounted to avoid a sudden shift or movement that would endanger the refrigerant lines. The precautions one must take vary with the size of the condensing unit, the kind of refrigerant, and in what situation the unit is to be placed.

The condensing unit must be placed where it cannot be harmed. It must either have a cage around it (small unit) or it must be in a separate room. It must have good ventilation, to permit escape of the refrigerants out of the room in case the unit develops a leak (windows for smaller units, forced exhaust for larger units). Also larger units must be protected from fire damage by using fire-proof self closing doors, etc. The better installations use a separate machine room for the refrigeration condensing units.

The electrical work must be done by a licensed electrical contractor.

The plumbing work must be done by a licensed Master Plumber.

To prevent violent rupturing or an explosion of the condensing unit due to excessive pressure, the code specifies:

1. High pressure cut-outs to stop the motor.
2. Pressure relief valves or rupture discs to dissipate the discharge slowly. These safety openings are piped to the outdoors by way of copper pipe connected by silver brazed joints (high temperature strength), Fig. 20-7. A spring-loaded safety valve with a synthetic rubber

20-7. A safety head (ruptured disc type) for Freon-12. The disc is made of silver. The safety head is obtainable having various rupture pressures from 175 psig to 1000 psig. The safety head is usually designed to rupture at 50 per cent above the usual operating pressure. (Black, Sivalls & Bryson, Inc.)

valve. It has interval pipe threads at both ends, Fig. 20-9. Fuse plugs are also used for those rare cases where the unit becomes overheated because of fire, Fig. 20-8.

All refrigerant lines should be permanently labeled with signs identifying the refrigerant.

20-14. INSTALLING COOLING COIL

The Code recommends limits of refrigerant for those cooling coils that would expose people to the refrigerant in case of leaks. Those coils installed in ducts should be cooled with a brine rather than a refrigerant depending on the total amount of refrigerant in the system.

The cooling coil should be mounted

firmly in the cabinet and it should be protected to avoid injury to the system. The refrigerant lines should be of hard copper pipe (L or K) or they should be protected with conduit wherever there is evan a remote possibilities of injury to the system.

The cooling coil should always be leveled when installed. A spirit level is the only reliable means to do this job.

20-15. INSTALLING REFRIGERANT LINES

The codes attempt to specify refrigerant lines that are permanent and safe. The codes recommend that strong piping be used (Type K (strongest) or L) and that the piping be protected by adequate supports and adequate guards. Some localities recommend that hard copper pipe that is exposed have at least .065 in wall thickness. The joints in the piping must be placed so they can be easily inspected. The joints must be made with strong fittings and the solders used must be of excellent quality. Soft solder can be used for most of the joints but if there is a possibility that fire may heat the piping, the joints should be silver brazed.

To avoid pinching or crimping the piping, the code recommends that the lines not be run through a floor but rather through a fire proof duct when going from one floor level to another.

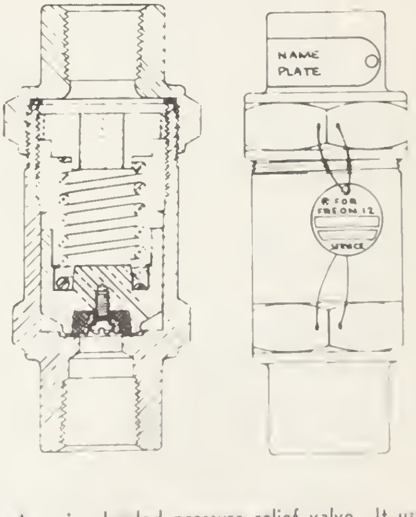
The code recommends that the piping always be supported by the building structure, meaning that the pipe should not be run across joints or studs where the unsupported part can be abused. It is recommended that the piping be at least 7 1/2 feet above the floor level when put across a room.

20-16. STREAMLINE FITTINGS

The size of commercial units has been increased quite steadily in the last few years and many units now have as much as 20 tons capacity. This is especially true with summer cooling or comfort cooling installations in air-conditioning plants. The sizes of the liquid and suction lines in these installations are frequently 3/8 in. and 2 in. in diameter respectively. It is

20-8. A fusible plug for liquid receivers.
(Mueller Brass Co.)

evident that flaring a 2 in. line is out of question. For this reason and because of other natural advantages of the joint, streamline fittings have become very popular and are used exclusively on large units. These fittings as described in Chapter 2 consist of a drop-forged or extruded fitting with a machined recess of sufficient size to receive the hard copper tubing. The clearance between the two is a matter of a few thousandths of an inch.



20-9. A spring loaded pressure relief valve. It uses a synthetic rubber seat. It is available in a variety of pressure ranges.
(Henry Valve Co.)

When this joint is heated and solder is fed to the surface, capillary action draws the solder into the space between the two, forming a very strong joint. The soldering of hard copper tubing joints must be expertly done or considerable trouble will result in bad joints and leaks. One should only attempt this work after considerable practice. Hard drawn copper tubing which is seamless has a greater wall thickness than the annealed copper tubing. It comes in 10 or 20-foot lengths rather than in rolls. The ends are either capped or plugged. The tubing is brazed or soldered to the fittings. When making an installation of this kind, extreme care should be taken to use fluxes and solders recommended by the manufacturers, and also to have the ends of the tubing square to prevent any solder from running into the tubing. See Paragraph 2-1.

20-17. SPECIAL TUBING

Copper tubing normally comes with no special finish provided for the inside or the exterior surface. This permits the copper to become corroded if exposed to certain corrosive elements, such as running the tubing through liquid or through air saturated with acid fumes or corrosive elements of any kind. In places where sanitation is of primary importance, tubing with tinned surface is used. A typical example of this is the installation where the copper tubing runs into a cabinet and is connected to the cooling coil. That portion of the tubing inside the cabinet is subject to the moisture saturated air of the cabinet and could eventually become corroded. Using tinned tubing prevents this. One company uses tinned tubing exclusively, because the company believes the sanitation aspect is important enough to warrant the extra expense.

Where the tubing is used to convey beverages such as beer between the kegs and dispensers, soft drinks, carbonated beverages, etc., many local codes require the use of special tubing. One such tubing is block tin tubing. It is available in rolls and comes in 1/4 ID and 3/8 in. ID sizes.

Stainless steel tubing is considered the best for carrying beverages. It is available as follows:

1/4 OD with a .020 in. wall thickness
5/16 OD with a .020 in. wall thickness
3/8 OD with a .025 in. wall thickness.

These tubes will insure a maximum of sanitation for the beverage tubing and a maximum life for the cooling water tubing. Both of these tubes are best fastened by solder or sweat connections.

20-18. REFRIGERANT LINE CONNECTIONS

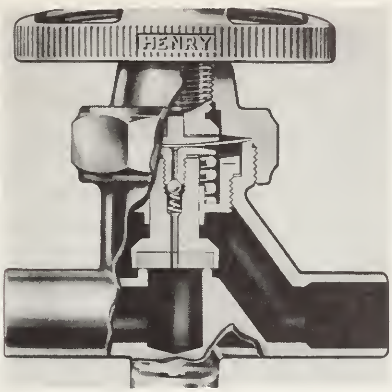
There are two common methods of installing a multiple installation as it concerns the installing of the tubing.

One method is to have a common liquid line and common suction line and to tap the various cooling coil liquid and suction lines to it at the most convenient points.

The other method is to use a clustering system wherein all the various lines are brought to a common point and connected through a hand valve to a manifold line. From this point to the compressor a larger suction or liquid line is run. The latter method predominates at the present time and is the neater and more convenient installation to use. This method does not have to be strictly adhered to in cases where one coil is at some distance from the box, necessitating a duplication of long runs. The manifolding case of a code installation is usually on the wall near the condensing unit.

An important item to be kept in

mind at all times is that every fitting used, and every bend put into the refrigerant and suction lines, decreases the efficiency of the installation. The number of these used should be limited as much as possible.



20-10. An installation valve showing the means for mounting the valve on a panel. (Henry Valve Co.)

Remember that one should either remove the inner parts of the valves while the tubing is being soldered to the valve or wrap the valve with a wet cloth. Take care not to allow moisture to enter the valve.

20-19. REFRIGERANT LINE VALVES

All valves are to be hand operated. The codes require that these valves be of such construction that anyone may shut them off on short notice without the need of special tools. The valve uses a hand wheel mounted permanently on the valve. These valves are provided with brackets whereby they may be attached firmly to a panel. The valves commonly come in two styles. In one style the valve shuts off just one of the three connections made to the valve, Fig. 20-10. The other two, remaining uncontrolled, permit the passage of refrigerant to the remainder of the system. The other style valve is a one way valve and stops the flow of refrigerant when turned in (clockwise). The older style valves were of the lead and graphite packing style, but packless valves are now becoming popular. The manipulation of the code installed unit, upon starting, to insure long and efficient refrigeration, is precisely the same as described in starting the non-code installations. This does not complete the installation regulations, however, because in all code installations an inspector is usually assigned to check over the installation before the unit may be operated.

20-20. TESTING CODE INSTALLATIONS

Code authorities require that permits be taken out before either an installation can be made or a major service operation be performed in commercial units. Specifications of the proposed job are presented when requesting a permit. Permits are not issued unless the specifications presented meet the code requirements.

On completion of the work an inspector is called, and his sanction must be given before the unit may be run. Some localities require that the refrigeration installation men be licensed.

The inspector upon reaching the premises, checks the installation to see if all the work has been done according to specifications and code, and then proceeds to test the system. His testing primarily consists of checking for leaks and checking the unit for safety. He does this by building up the required pressures in the high and low sides of the system. These pressures vary with the kind of refrigerant used in the system. If no leaks are indicated at the pressures established, the inspector sometimes checks the system further by producing a vacuum on all of the systems and if this vacuum is maintained over a certain period of time the

installation is approved. These code regulations have eliminated many troublesome features in the installation work. Most of the larger refrigeration companies followed these methods long before they were required by law because code rules are only a statement of good safe practice which insures satisfactory operation of the installation. Experience has shown that code installations are good business practice.

After the system has been approved, the installation man should always make a record of the running behavior

20-11. A recording pressure gauge. (Electric Auto-lite Co.)

of the unit for at least 24 hours. Figure 20-11 illustrates a pressure recorder, making a 24 hour record of the low side pressures of the installation. Any variations in the cycles will quickly reveal needed adjustments.

20-21. SERVICING COMMERCIAL UNITS

Commercial refrigerating units are available in a great variety of forms. Chapters 18 and 19 describe in detail the design, construction and operation of these units.

The small units such as self contained beverage coolers of hermetic design are serviced in the same manner as the domestic systems. The details are given in Chapter 17.

Many of the commercial systems are self-contained but use the conventional system with motors, belts, and compressors. The servicing of these small conventional systems is described in Chapter 11.

The service shop procedures explained in Chapter 12 are useful for both domestic and commercial refrigeration.

The servicing of the larger commercial systems is controlled in most communities by the Local Refrigeration Code. Any major repairs or changes to a commercial system can only be done by licensed contractors and the service work done must be checked by the refrigeration inspector.

The plumbing and electrical service work should be sub-contracted to licensed plumbers and electrical contractors.

20-22. SERVICING CONDENSING UNITS

Condensing units come under several divisions - water-cooled and air-cooled - and involve the compressor, the condenser, liquid receiver, the various motor controls, and water valves. The compressor itself may be tested for efficiency as described in Chapter 11, but such things as "lack of refrigerant" present new problems.

An air-cooled condenser gives the same symptoms when there is a lack of refrigerant as those explained in Chapter 11, but the water-cooled type presents a different problem. Because of similar variations throughout the mechanism, the study is divided into individual parts of the condensing unit.

The condensing unit should be cleaned externally as thoroughly as possible, using rags and a non-flammable cleaning fluid. The belts should be checked for alignment and tautness.

If there is any decided pounding sound occurring regularly in the compressor, the customer should be in-

formed of this, and a recommendation made that the compressor be overhauled as soon as possible.

The amount of refrigerant in the system should be very carefully checked according to methods explained in Chapter 19. The water flow should be so adjusted that the temperature rise is no more than 15 degrees as the water goes through the condenser. The motor control should be inspected to determine whether it trips freely and whether the points, if any, are clean. A fine small file is the only cleaning device recommended for these points.

20-23. SERVICING COMPRESSOR

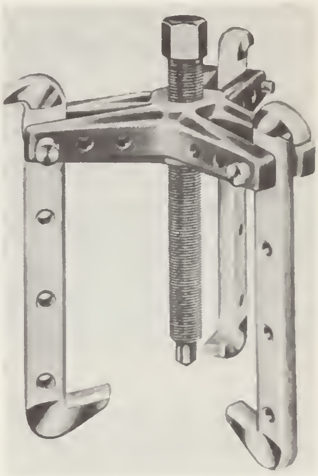
To test the compressor for efficiency, the service man may use the following methods:

1. Determine the vacuum that the compressor will develop by turning the suction service valve all the way in after installing a compound gauge in the gauge opening. Record the highest vacuum obtainable against the normal head pressure for the refrigerant being used. Also, record the time. If the compressor cannot produce a vacuum of greater than 20 inches of mercury against its normal head pressure, it should be overhauled. After a vacuum has been drawn, the compressor should be stopped; if the vacuum drops rapidly, it means that either the exhaust valves in the compressor are allowing the refrigerant to leak back into the crankcase, or that the crankshaft seal is leaking.

2. To determine if the exhaust valve is leaking, turn the discharge service valve all the way in after installing the high pressure gauge in the gauge opening; then turn the compressor over very slowly by hand. If the exhaust valve is leaking, the head pressure as indicated by the high pressure gauge will go up and down as the compressor turns over, but if it is holding, the head pressure will increase to a certain point where it will remain constant.

3. To determine whether or not the crankshaft seal is leaking, close the suction service valve, pump as high vacuum as possible on the crankcase of the compressor, and with the discharge service valve and suction service valve turned all the way in, keep the compressor running. If there is a low side leak, the head pressure will gradually increase with the running of the compressor, indicating that gas or air is being drawn in on the low side of the compressor.

4. An intake valve leak is indicated by the inability of the compressor to produce a high vacuum, but whatever vacuum is produced is maintained after the compressor is shut off provided the exhaust valve is holding.



20-12. A universal type flywheel puller. (Duro Metal Products Co.)

If the compressor must be removed for overhaul, the handling of the compressor because of its weight presents a difficult problem. The serviceman should avoid straining himself by assuming any awkward position when lifting the compressor. He should be careful not to slip on oil or loose tools. Carts, small hydraulic hoists,

etc., are available that should be used to move heavy compressors.

If possible remove the flywheel, before moving the compressor as any undue strain on the flywheel may injure the crankshaft, and/or the crankshaft seal. The flywheel can be easily removed by using a universal flywheel puller and by supplying heat to the flywheel hub as the wheel puller is drawn up snugly, Fig. 20-12.

When installing the compressor, the condensing unit base should be cleaned. All the hold down bolts should be used, and the bolts should be tightened evenly. The compressor and motor must be carefully aligned. The shaft must be parallel and the flywheel and the pulley must be in line. If one has difficulty installing the hold down bolts, masking tape may be used to hold them temporarily, or string may be used to pull the bolts into position. A universal socket is handy for holding bolts that seem inaccessible. New gaskets should always be used when mounting service valves.

20-24. SERVICING CONDENSER

The troubles encountered in commercial condensers vary with the type of condenser used. However, air in the system, too much refrigerant, not enough refrigerant, too much oil or a corroded interior are common to all types.

Whether the condenser is air or water-cooled, too much refrigerant, too much oil, or a corroded interior of the condenser will produce an excessive head pressure. Air in the system will also produce this condition. Remember that the purpose of the condenser is to remove heat. The condenser will fail to do its job if the heat transfer surfaces are inefficient, or if the heat removing medium (air or water) is not in the correct volume or temperature.

To determine what is responsible for a poor condensing condition, one should proceed as follows: Install the gauge manifold, see Paragraph 11-5, and determine the head pressure. Compare this pressure with what the pressure should be.

20-25. SERVICING AIR-COOLED CONDENSERS

The correct pressure may be determined by adding 30 F. to 35 F. to the room temperature, if it is an air-cooled condenser, to obtain the refrigerant temperature on the interior of the condenser. Using this corrected temperature, refer to the refrigerant charts, Chapter 8, for the correct head pressure.

20-26. SERVICING WATER COOLED CONDENSERS

If the unit is water-cooled, add 20 F. to 25 F. to the temperature of the water just as it is leaving the condenser to obtain the refrigerant temperature. The correct head pressure is then obtained from the refrigerant chart. The unit must be running for these conditions to hold true.

If the head pressure exceeds this value by more than 5 pounds, purge the system through the discharge service valve gauge opening for 10 to 15 seconds; then run the condensing unit again. To determine whether or not the trouble is excess refrigerant, or air in the system, stop the unit and purge as before for 15 to 20 seconds. If the pressure drops somewhat, it is air in the system.

If the pressure does not drop, continue to purge the unit until that part of the condenser and liquid receiver which is full of liquid refrigerant, becomes cold. Some condensing units have small valves, that can be used to

check liquid levels. A liquid level sight glass is also available. It can be connected to the top and bottom of the receiver. When the pressures are equalized the liquid level in the sight glass will be the same as that in the receiver. This will quickly reveal the level of the refrigerant in the condenser and liquid receiver, and one may easily judge whether or not this is the correct amount. An excess amount of oil in a system is indicated by the erratic refrigeration obtained, and a continuous slugging or pumping of oil in the compressor, especially just as it starts after an off-part of the cycle.

A corroded condenser is determined by noting the liquid line temperatures of the refrigerant. In case the amount of refrigerant is correct, and if the other troubles just mentioned are not prevalent in the system, a corroded condenser will produce a hot liquid line in an air-cooled system; also in a water-cooled condenser, it will produce a temperature in the condenser considerably above that to be expected. If all other possible causes of excessive head pressure are eliminated according to the above methods, a badly corroded condenser is probably the cause. Scale may be removed from some water-cooled condensers by using a power driven wire brush, Fig. 20-13.

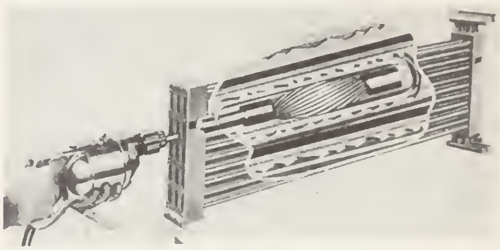
20-27. SERVICING EVAPORATIVE CONDENSERS

Evaporative condensers and cooling towers are subject to deposits from the cooling water. These deposits must be removed periodically or they will act as coil insulation. The deposits can be reduced materially by using water softener chemicals in the water. Such chemicals can be obtained from any wholesale supply company. If deposits have formed, they can be removed by scraping or by using a weak acid solution, followed by a soda solution rinse and wash. Water-cooled condensers should not be placed in a location which may be subjected to freezing temperatures.

In the event a water-cooled condensing unit is to be shut down and perhaps subjected to below freezing temperatures, the condenser coils must be completely emptied of water. This may be done by blowing out the coils with air.

20-28. SERVICING WATER VALVES

Water-cooled condensers require attention frequently because of incorrect water flow. This trouble is sometimes due to the water valve or the screen. See Chapter 19 for details of construction of these valves.



20-13. A tube within a tube condenser being cleaned by using a power driven wire brush. (Halstead & Mitchell)

The main purpose of the water valve is to provide water when the unit is running and to stop the water flow when the unit is idle. Some of the troubles caused by the water valves are:

1. Too little water flow.
2. Too much water flow.
3. Water flow does not stop when the unit is idle.

A water control valve will only operate correctly if the installation is correctly made and if the water is clean.

20-29. RESTRICTED WATER FLOW

Common troubles encountered with

water valves if the water flow is too little are as follows:

1. A leaky valve
2. A clogged screen
3. A chattering valve
4. The adjustment of the valve turned out too far
5. A sediment-bound valve
6. A leaky bellows

In addition to these troubles, the water-cooling system may present the following difficulties: Many of the water-cooled systems use a 2-foot length of rubber hose connected between the water pipe running along the wall and the condensing unit water lines in order to eliminate transmitting the condenser vibration into the plumbing system of the building, and also to eliminate breakage of tubes from this vibration. The cold water inlet hose connection presents no difficulties and this hose will ordinarily give many years of service. However, as the water circulates through the condenser and cylinder head of the compressor, it sometimes becomes quite warm. This warm water, as it passes through the outlet hose connection, tends to deteriorate the inner rubber of the hose, resulting in a blistering of its inner wall. This will eventually clog the hose and restrict or stop the flow of water through the condenser.

Occasionally, someone may partially or completely shut off the water supply by closing the hand-operated valve installed in the system. The two most common complaints which indicate troubles with the water circulation are a lack of cooling in the condensing unit and too great a consumption of water. If the water circulation is stopped, the refrigerating system will start to short cycle, due to the functioning of the high pressure switch since these systems are always provided with a high pressure safety motor control for this purpose. As the head pressure of the machine builds up due to a lack of cooling, pressure is soon reached at which this control will open a switch stopping the motor. As soon as the motor is stopped, the head pressure drops rapidly, permitting the high pressure control to turn the motor on again. This short cycling will continue indefinitely unless the trouble is remedied. Such a condition is a severe strain on the motor and will not give satisfactory refrigeration.

20-30. TOO GREAT A WATER FLOW

Too much water flow will give very satisfactory refrigeration, but the amount of water consumed will be in excess of that needed and greatly increase the cost of operation. Three things which may cause too great a water flow are:

1. Too high a water pressure
2. A leaky water valve
3. A water valve out of adjustment in such a way as to hold a valve too far open

The condition of too high water pressure is seldom encountered unless the water supply pressure is uncontrolled. If encountered in one machine, it will perhaps be true for all the machines in that locality.

To determine whether the condition is due to a leaky valve or to a valve open too far, ask questions of the proprietor as to whether anyone has been working on the machine. If the machine has not been tampered with, and the trouble has just started to make itself evident, the trouble is usually a leaky water valve. This will be indicated by a continuous flow of water on the off cycle. Quite often a leaky water valve may be due to foreign matter lodging between the valve and valve seat. One can usually dislodge this material by flushing the valve. This flushing may be done by using a screw driver to pry the valve open several times.

20-31. TRACING WATER CIRCUIT TROUBLES

The principal problem is to determine whether the water valve is causing trouble, or if it is caused by some other part of the water circulating system. To locate the exact source of the trouble, one may disconnect the joints where the hose is fastened to the rest of the system. By disconnecting the exhaust water hose from the machine unit, one can readily determine whether the water is flowing as far as this point. If the water is coming as far as this point, the connection should be resealed and the other end of the hose disconnected from the wall pipe. If the water does not flow up to this point, the trouble is probably in the exhaust rubber hose of the system. If the water does not flow up to this hose, one should determine whether the water is coming as far as the water valve by disconnecting the rubber hose used as the inlet connection. If the water flows through the hose, the sources of trouble are the water valve and the condenser proper. To check these sources, reseal the inlet rubber hose from the system and disconnect the water valve from the condenser. If the water flows through the water valve, but does not go through the condenser, the trouble is a major one necessitating a replacement or cleaning of the condenser water tubes. However, if the water does not flow through the water valve, it must be disconnected from the system and repaired or replaced.

Water hammer (a very noisy condition) can usually be eliminated by putting a short vertical pipe into the water line just ahead of the water valve.

20-32. REMOVING WATER VALVE

To remove an electrical water valve from the system, one must open the hand switch that controls the circuit to the motor and remove the water valve wires from the motor circuit. Since these wires are usually soldered and taped, it will be necessary to cut them. Before disconnecting the water valve from the water system, the water supply must be shut off at the hand valve. If the serviceman does not have a replacement valve on hand, the water system may be temporarily connected without a water valve and the water flow regulated with the hand shut-off valve.

Some pressure operated water valves are difficult to remove from the system because the valve is connected to the high pressure side of the condensing unit. The pressure tube for these valves is usually connected into the cylinder head of the compressor, although some manufacturers connect this tube into the liquid line of the unit. A hand shut-off valve for this tube is sometimes provided, and if so, the removing of the valve is very simple. In case the tube is connected to the cylinder head of the compressor, the following is the procedure to remove it:

1. Install the gauge manifold.
2. Turn the suction service valve all the way in.
3. In case the refrigerant is methyl chloride, Freon -12, or Freon -22, run the compressor until the pressure in the crankcase registers 0 psi. If the system uses sulphur dioxide, one must evacuate the crankcase and then balance the pressure by cracking the suction service valve.

Note: Be very careful of oil pumping which sometimes will occur before the pressure of 0 psi can be reached with Freon -12, Freon -22 or methyl chloride. This oil pumping usually occurs when a sulphur dioxide unit is evacuated to a 10-inch or 12-inch vacuum.

4. Heat the water valve line and the water valve bellows very carefully with a torch for three or four minutes until both of these become quite warm to the hand. This operation will drive the liquid refrigerant, which has condensed in this tube and valve, back into the condensing unit, leaving only a small quantity of high pressure gas in this tube.
5. Turn the discharge service valve all the way in.
6. Clean the joints to be opened.
7. Disconnect the pressure tube from the water valve.
8. Plug the refrigerant pressure tubing openings immediately.
9. Heat the water valve again very gently, especially if it is a sulphur dioxide system, for often a quantity of liquid refrigerant becomes oil bound within this bellows chamber, and releases with explosive force a few minutes after the valve is opened to the atmosphere. Note: Be very careful not to point these refrigerant openings toward anyone because of the danger of being hit by the refrigerant.
10. Shut off the water supply.
11. Disconnect the water valve from the water line and replace it with a good one or connect the water lines directly. The water valve is now ready to be dismantled and repaired.

Some water valves are designed to permit the removal of the valve body without disturbing the refrigerant connections (bellows, etc.). To disconnect one of these valves, simply shut off the water, disconnect the valve body from the water lines and bellows body.

20-33. REPAIRING WATER VALVE

To completely overhaul a water valve, in addition to cleaning it, which may best be done with wire brushes, the valve and valve seat must be repaired. The valve seat, which is made of brass in most cases, may be lapped in a manner similar to lapping a compressor valve seat.

The valve proper usually consists of fiber, rubber, or Bakelite material and it should be replaced with a new part. In cases of emergency, however, this valve may be trued up by using a fine grade of sandpaper backed up by a level surface.

Occasionally, where the valve actuating stem passes into the valve body proper, a packing gland is used to seal the joint. This packing is the typical asbestos, graphite, and lead packing. If the packing nut has been turned all the way down, the packing should be replaced.

20-34. ADJUSTING WATER VALVE

After cleaning and repairing a water valve, it should be tested and adjusted before being replaced in service. If the

Refrigerant	Water In Temperature F										
	50	55	60	65	70	75	80	85	90	95	100
Sulphur dioxide.	26.5	30	34.5	38	43	47.5	53	68	65	70	77
Methyl chloride.	47	52	57	63	70	76	82.5	89	96	103	111
Freon-12........	56	62	68	74	80	87	93	101	108	117	125
Ammonia.........	98	108	119	130	140.5	152	164	177	191	205	220
Freon-22........	95	104	113	123	133	144	155	158	180	194	208

20-14. A table of water valve pressure settings.

maximum temperature of the water supply is 75 F. the valve should be adjusted to open at the following pressures: 48 pounds per square inch for sulphur dioxide; 76 psi for methyl chloride; 87 psi for Freon -12; 144 psi for Freon -22; 152 psi for ammonia.

If the water-in temperature is different from this, one may adjust the valve to its correct opening pressure using the following rules: for every 54 degrees change in water temperature, change the opening pressure of the valve 6 psi for sulphur dioxide, 5 psi for methyl chloride, 7 psi for Freon -12, 11 psi for Freon -22 and 12 psi for ammonia. For example, if the water temperature in the methyl chloride system is 65 F. instead of 75, the opening pressure of the water valve should be lowered to 64 psi, Fig. 20-14.

A valve should also be tested for leaks at the same time that it is being adjusted. This may be done by connecting an air pressure line to one of the water openings of the valve. In order to adjust and test the pressure operating bellows, which controls the water flow, connect another air line and a pressure gauge to this fitting. No air should flow through the water valve until the correct control bellows pressure has been reached. Necessary adjustments may be made to obtain this condition.

20-35. SERVICING LIQUID RECEIVER

The liquid receivers used in most commercial systems serve as refrigerant storage tanks and are usually constructed of a steel shell welded or brazed at the joints.

The shell and tube liquid receiver, which has a water coil built into it, sometimes develops leaks. Because of corrosive action of the water and refrigerant under certain conditions, the copper tubing which is used to carry the water eventually corrodes through; the resultant leak forces the refrigerant from the system into the cooling water. A leak of this kind is detected by the release of refrigerant at the water drain. Also, leaks occasionally occur at the joints where the water-cooling coil is attached to the liquid receiver and may be due to abuse or to corrosive action. In such a case, the condenser should be replaced with a new one.

If new parts are not obtainable for the machine, a fairly satisfactory repair may be made as follows: The water tubing, if eaten through within the liquid receiver, must be removed. The liquid receiver should be mounted on a lathe and the end of the receiver cut open. This permits removing the old water coil and putting in a new one. The new one must have the same length of tubing as the one removed, or the capacity of the condenser will be changed materially. The new coil is usually made up by winding it on a drum mounted on a lathe. The tubing is then put in the liquid receiver and the joints are silver brazed. The end of the liquid receiver that was removed may now be replaced after the interior has been cleaned thoroughly. The joint may be either silver brazed or welded.

All liquid receivers above a certain size must be equipped with safety release valves. The National Refrigeration Code, Chapter 29, specifies the type, location, size, and piping for such relief valves. A receiver repair must be done under the sanction of Local inspectors.

20-36. CHECKING REFRIGERANT CHARGE

One of the most detrimental conditions which may occur in a refrigerating system is to operate the refrigerating unit without sufficient refrigerant. It results in abuse to all of the valves in the unit and usually results in con-

tinuous motor operation. Several methods may be used to indicate whether or not a refrigerator has an adequate supply of refrigerant.

In a low side float system the lack of refrigerant usually shows up at the most remote coil, or the coil which is the greatest vertical distance from the liquid receiver. If the refrigerant is low, this coil will not have enough liquid refrigerant in it to close the float valve. As a result the coil will make a continuous hissing sound while the refrigerant gas flows through it. This condition will be accompanied by a warm liquid line which will be several degrees warmer than the suction line. This may be easily checked by feeling the two lines where they are attached to the coil.

A dry or expansion valve system is much more difficult to check for quantity of refrigerant. The first indication of insufficient refrigerant may be obtained from the appearance of the expansion valve body. Under normal conditions the body of the valve frosts over evenly as far back as the liquid line nut. In case the system has insufficient refrigerant, the expansion valve body adjacent to the liquid line will not frost. This frost method cannot be used for above freezing coil operating conditions.

A common method of checking for quantity of refrigerant is to check the quantity actually in the liquid receiver and condenser. One way to do this is to determine the high side head pressure.

If the unit is air-cooled, the head pressure for the system should correspond to refrigerant temperatures 30 F. to 35 F. higher than the room temperature while the unit is running.

If the unit is water-cooled, the head pressure should correspond to refrigerant temperatures approximately 10 F. higher than the temperature of the water leaving the condenser. The temperature of the water in this case should be checked at the point where it leaves the condenser and not at the end of a long drain pipe. If the head pressure, as indicated on the gauge, is below normal as much as 10 psi it indicates a lack of refrigerant.

A popular method to check for refrigerant quantity is to mount a glass sight gauge in the liquid line and note if there are any gas bubbles going up the liquid line. Bubbles indicate insufficient refrigerant, Fig. 20-15. A head pressure of 65 psi or more must be used because at low head pressure bubbles may appear regardless of the amount of refrigerant in the system. If no bubbles appear in the sight gauge at the above pressures, the machine has sufficient refrigerant. If there is a restriction in the line ahead of the sight gauge bubbles may appear even though there is sufficient refrigerant in the system. If possible, the sight glass should be mounted between the receiver and the dehydrator.

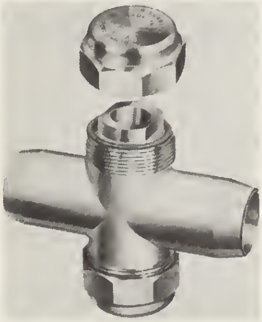
Some machines are equipped with refrigerant liquid level indicators such as pet cocks mounted in the side of the liquid receiver at definite heights. If the pet cock is opened and liquid refrigerant comes out, the level of the refrigerant is at least up to this height. Two pet cocks are usually provided. Gas should come from the top one, while liquid refrigerant should come from the lower one, when opened.

The Frigidaire Corp. has designed a liquid level detector which is in use in this company's commercial high pressure sides of 1/3 H.P. and over. A float to which is attached a permanent magnet is placed in the liquid receiver. A well is built into the wall of the liquid receiver in which a gauge may be inserted by the service man. The permanent magnet, attached to the float on the inside of the receiver, operates the gauge needle to indicate the corresponding level of the refrigerant. The gauge is usually calibrated

by gauge readings of 1/4, 1/2, and 3/4 full, etc.

Some companies use a glass sight gauge attached to the liquid receiver to indicate the liquid refrigerant level.

In the liquid receiver type of water-cooled unit in which the water coils are located within the receiver, the amount of refrigerant within the system may be checked by determining the temperature differences of the receiver. The division point between the part of the tank filled with hot gas and the part filled with cold refrigerant will be indicated by a temperature difference which may be easily found by feeling of the tank with the hand.

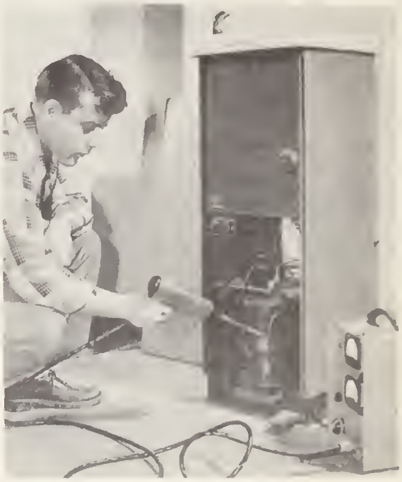


20-15. A sight glass for mounting in a liquid line. (Mueller Brass Co.)

Another method of determining the quantity of liquid refrigerant in the liquid receiver consists of turning off the cooling water to the condenser, allowing the compressor to operate. If the liquid line warms up quickly it is an indication of insufficient refrigerant. Also it may be noted in this connection that the head pressure rises after the water is shut off. If the compressor is now stopped and the head pressure drops rapidly, it is another indication of a small amount of liquid refrigerant in the liquid receiver.

Still another method of checking for the quantity of liquid refrigerant consists of shutting the machine down and purging the liquid receiver. The boiling of the refrigerant in the liquid receiver, when the pressure is reduced, will cause the part of the receiver that is filled with liquid to get very cold and frost over. This method is rather expensive and should only be used as a last resort for it wastes considerable refrigerant.

Lack of refrigerant must be due to a leak of some kind in the equipment. A very careful check should be made of



20-16. An electronic leak detector being used to check a self-contained water cooler. (General Electric Co.)

all joints and parts that could possibly leak before the unit is recharged and put into service. The most sensitive leak detector is the electronic type shown in Fig. 20-16.

20-37. CHARGING A COMMERCIAL SYSTEM

Charging commercial systems is very similar to charging domestic machines by charging into the low side. To charge a commercial system the storage cylinder should be attached to the gauge manifold.

The charging lines must be clean, the lines must be purged to rid them of air and the connections tested for leaks prior to the actual charging operation. Remember to always wear goggles when

transferring refrigerants.

The principle of operation is to allow the service cylinder to become a temporary cooling coil in the system. As the compressor runs, it will remove gas refrigerant from the cylinder as well as continuing to remove gas from the cooling coils.

The charging can be speeded by using the suction service valve to reduce the flow from the regular cooling coils and speed the evaporation in the service cylinder. Hot water may be applied to the service cylinder to help speed the evaporation. The low side pressure should be kept at normal levels as too high pressure will overwork the compressor and too low pressures may cause oil pumping.

	Sulphur Dioxide		Methyl Chloride		Freon-12		Freon-22	
	Flooded	Dry	Flooded	Dry	Flooded	Dry	Flooded	Dry
1/2 H.P.unit	5	2 1/2	3	1 1/2	3	1 1/2	3	1 1/2
1 H.P.unit	10	5	6	3	6	3	6	3
1 1/2 H.P.unit	15	7 1/2	9	4 1/2	9	4 1/2	9	4 1/2
2 H.P.unit	20	10	12	6	12	6	12	6

20-17. A table of approximate amounts of refrigerant which may be safely added to a system which is low on refrigerant.

This system insures clean refrigerant due to the distilling action during evaporation of the refrigerant. A service man must be present during the charging. A service cylinder must not be left connected into a system.

It is very important that liquid refrigerant not be allowed to reach the compressor. The liquid is not compressible and the compressor valves, and even the bearings and rods may be ruined if the compressor should pump liquid.

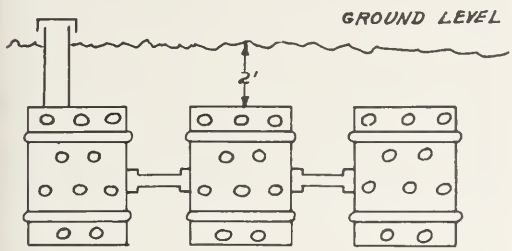
Although it is not recommended, some service men do put liquid refrigerant into the high pressure side of the system. This is a dangerous practice because dynamic hydraulic pressures are possible that may rupture the lines, etc., and cause considerable damage. However, this system can be used to put the initial charge into a system if done very carefully. If one inverts a cylinder and it has a higher pressure than in the system, liquid refrigerant will be forced into the system.

If the unit is water-cooled, the pressure in the liquid receiver with the water flowing will be sufficiently below that of the pressure in the cylinder to permit opening of the two valves after the charging line has been purged. The pressure difference will force refrigerant from the cylinder into the system. If the unit is air-cooled, the pressure in the refrigerant drum will have to be increased. This may be done by using the compressor to pump gaseous refrigerant into the drum and increase its pressure. In detail this method is as follows:

1. Connect the refrigerant cylinder to the gauge manifold.
2. Run the compressor with the discharge service valve turned all the way in until a pressure of 125 to 135 pounds is built up in the cylinder.
3. Stop the compressor.
4. Invert the refrigerant drum (be careful not to injure the line).
5. Turn the discharge service valve part way out.

The high pressure on the surface of the refrigerant in the drum will force the liquid into the system. While the liquid is flowing into the high side, a gurgling sound may be heard. If this

sound ceases abruptly, it means that the cylinder has been emptied. Use this method only if all the refrigerant has been removed from the system. The amount of refrigerant to be put into a system that is being serviced for lack of sufficient refrigerant must be governed by the service man's knowledge concerning the size of the system, the apparent amount of refrigerant in the system, and the kind of refrigerant used. See Figure 20-17.



20-18. A method of disposing of used refrigerant and used refrigerant oil.

20-38. DISCHARGING SYSTEM

Whenever it is necessary to discharge a system for repair purposes the refrigerant, if not in excessive quantity, should be discarded, using the method of purging it out of the nearest window by means of 1/4-in. copper line. Place an oil trap in the line to make sure that the oil in the refrigerant will not harm any surrounding property.

This method cannot be used for ammonia or sulphur dioxide because of the odors. Most localities forbid purging refrigerant into a sewer system. Small quantities of sulphur dioxide may be neutralized with lye. If the refrigerant is to be put back into the same machine, or if facilities are available for distilling it, it may be temporarily stored in a clean refrigerant drum. One must remember that this refrigerant will always have an oil charge. Some large companies save all refrigerant, redistill, and process it for further use. This amounts to a considerable saving when great quantities of refrigerant are used. See Paragraph 12-25 for methods of distilling refrigerant.

To get rid of refrigerants that have been removed from a system by storing in a service cylinder, it is possible to purge the refrigerant into perforated containers buried in the ground. The ground absorbs the oil and refrigerant in great quantity and seemingly without any ill effect, Figure 20-18.

20-39. SERVICING LIQUID LINE

The liquid line contains several important items needed to be checked by the service man, including:

1. The size of the liquid line.
2. The hand shut-off valves.
3. The liquid sight glass.
4. The screen or filter.
5. The dryer or dehydrator.
6. The vibration absorber.
7. The connections.

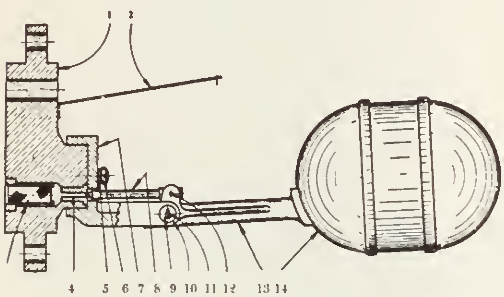
When diagnosing the troubles of a system, the service man's first problem is to determine if the various parts of the system are of sufficient capacity. It is important that the liquid line be as large as the condensing unit liquid receiver valve connections. Check to be sure that reducer fittings have not been used. Also see Paragraph 19-54 for recommended liquid line sizes. A sight glass should be installed in the liquid line prior to the mounting of the filter screens, and dehydrators.

A special precaution that all service men must remember is to always have at least one end of a liquid line open when servicing the unit, otherwise a temperature rise will create very high hydrostatic pressures and this pressure may burst the line. One should be especially careful if a solenoid valve or a clogged screen or dehydrator is in the line.

When admitting liquid refrigerant into a liquid line by opening the liquid receiver service valve, always open the valve very slowly or the sudden rush of liquid may injure the screen and may pack the desiccant in the dryer so firmly that it will soon clog.

20-40. SERVICING CLOGGED SCREENS

One trouble some times found in multiple systems is the clogging of the screens located at each individual coil. These screens are located in the inlet to the refrigerant control. One low side float construction has the liquid line valve bolted on the header, and the screen is inserted in a little pocket between the liquid line service valve and the header. If a service call is made and it is found that all cooling



20-19. A low side float mechanism showing the location of the screen.
(Kelvinator Div., American Motor Corp.)

coils except one connected to a multiple system are operating satisfactorily, and this one coil is not giving any refrigeration whatsoever, the trouble may be due to one of three things, either the needle is stuck closed, the screen is clogged, or the float is completely oil bound. The following service procedure is recommended:

A completely oil bound float may be detected by rocking the cooling coil; the needle will open momentarily during this procedure. If it is a stuck shut needle, the orifice may be broken open by tapping the header lightly. If neither of these methods determine the trouble, it is probable that a clogged screen is the cause of the trouble, Figure 20-19. In some multiple low side float systems, one must turn the liquid line service valve all the way in after loosening the packing nut. Then determine if the low side pressure is near atmospheric by putting a compound gauge on the condensing unit. If the pressure is near atmospheric the cooling coil is usually evacuated before the service man arrives on the premises.

This will be indicated by a warm cooling coil. Close the suction line valve and, after cleaning and drying the joint between the liquid line service valve and the header, this valve may be unbolted. When the connection (a gasketed one) is opened, a little liquid refrigerant may escape, but if sulphur dioxide refrigerant is used it may be readily neutralized with ammonia fumes. The screen is located at this point and is easily accessible to be replaced or to be cleaned. The recommended service practice is to carry several replacement screens and replace the clogged screen with a new one.

The screen in some low side floats is soldered into a fitting which in turn is mounted between the liquid line and the liquid line service valve. To remove this screen, the following procedure may be used. Since the screen is clogged, the refrigerant in the liquid line cannot be removed by evacuating it; but it may be removed by heating the liquid line. It is dangerous to overheat the line as it may decompose the oil and refrigerant in the line. Always heat only hot enough for the line to be slightly uncomfortable to the hand. This heating should continue from the coil to the nearest shut-off valve back along the liquid line. The valve on the cooling coil header should be closed

during this heating. This heating will drive the high pressure liquid refrigerant back into the main liquid line, leaving only gas. Shut off the valve located at the junction of these two lines. Now disconnect the liquid line nut from the liquid line valve on the coil header, after cleaning and drying it. As the liquid line is disconnected from this fitting there will be a surge of high pressure gas out of this line; but this cannot be helped unless a very tedious program of removing all the refrigerant from the complete liquid line system is followed. The screen fitting may now be removed from the valve and cleaned or replaced.

Upon assembling the coil after repairing the trouble, proceed as follows: Open the two liquid line valves after the unit has been assembled and then carefully test for leaks. When starting a coil in this case, the service man should always wait until he hears the float valve stop the flow of refrigerant. This policy will save many call-backs in case the needle is leaky.

Some low side floats, when opened to remove a screen, permit a slow seepage of air into the cooling coil through the needle orifice opening. This amount is negligible if the unit is assembled immediately. However, if the coil has been left open for a number of hours, the coil should be purged of air by loosening the suction service valve from the coil header and then cracking the liquid line valve. The resultant surge of gas will remove most of the air from the coil.

Needless to say when reassembling the unit, a new gasket should be used and the two gasket surfaces should be perfectly clean and smooth. A scraper made from an old flat file is a good tool for removing the old gasket. If possible, the service man should put a little refrigerant oil on the new gasket before installing it. Never use other than Monel or extra heavy cadmium plated bolts and cap screws on cooling coils. Always test for leaks.

The screens proper are best cleaned in the repair shop. One excellent method to clean a screen is to heat it very carefully - electric plate - and then quench it in water. This treatment quickly loosens most of the dirt. A weak solution of hydrochloric acid and water also does a good job. Pour acid into the water, never water into acid. Be sure to rinse the screen. Wear goggles when doing this job to protect the eyes from splatter. Thermostatic expansion valve screens may be serviced in much the same way.

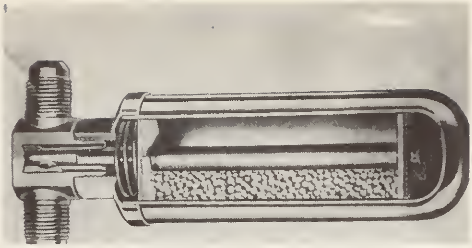
Master screens located at the receiver end of the liquid line are also serviced as stated. However, in some cases, the receiver must be discharged to permit removing the master screen.

20-41. MOISTURE IN SYSTEM

Many troubles in refrigerating systems may be traced to the presence of moisture in the system. Moisture, as it circulates through the system in the presence of the oil and the refrigerant causes many complex actions.

Moisture in the presence of sulphur dioxide builds up an acid condition, which corrodes the compressor parts and quickly ruins the entire system.

With some of the other refrigerants, the moisture combines with the refrigerant to form slight acids which, although very slow acting, eventually are a source of trouble. With Freon -12, Freon -22, methyl chloride, isobutane, Carrene -2, and some others, moisture in the system will freeze at the refrigerant control orifice, eventually clogging it. If immediate action is taken to remove all moisture or to make the moisture harmless, many troubles may be eliminated.



20-20. The T-Flo Drier. The refrigerant enters at the left, passes down through the middle tube and then upward toward the desiccant before leaving at the right. (Ansul Chemical Co.)

20-42 DRIERS (DEHYDRATORS)

Surveys show that about 80% of all service calls are either directly caused by, or, are traceable to moisture. Moisture in contact with refrigerants forms acid which corrodes metal, initiates oil breakdown, and forms sludge. These sludges plug driers, filters, screens, and small orifices such as capillary tubes. In addition, if the moisture is present in large enough quantities, it will form ice in capillary tubes and expansion valves, plugging them.

There are a number of ways of removing moisture from refrigeration equipment. These include high vacuum, slow steady flow of hot dry air, and several moderate vacuums broken with dry refrigerant. The most common method, however, of removing moisture is with the use of a liquid line drier. If the drying material has sufficient capacity in both the high and low moisture ranges and is fully activated, it can replace all of the foregoing methods. The conventional straight through drier consists of a tube, (brass, copper, or steel) filled with a chemical (desiccant) which will remove moisture by absorption (activated alumina, or silica gel) or absorption (calcium sulphate). Both ends of the tube usually contain filter elements, and the end caps are fitted with either flare or soldered connections. One design of liquid line drier allows the fitting to stay in the line and only the drier cartridge is changed. See Fig. 20-20.

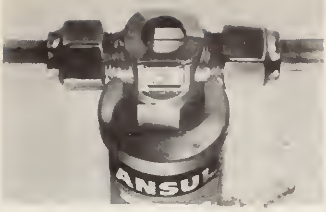
The most common desiccants(chemicals in the drier shells) are Type H and Type F activated alumina, silica gel, and calcium sulfate. Calcium chloride, once widely used, is no longer used in any quantity.

Driers are usually installed in the liquid line. They may be installed in the suction line as a temporary installation to protect the compressor after a hermetic motor burn out, or after severe oil breakdown. Also in cases of extreme space limitation, driers may be placed in the suction line. All of the common refrigerants can be successfully dried with the drier in either the liquid or suction line.

Refrigeration equipment should be dried below 15 parts per million if "Freon-12" is used and below 25 ppm if "Freon-22" is used. The beginning of corrosion in "Freon-12" is 15 ppm. It is not known for "Freon-22," but experience shows that corrosion, oil breakdown, and motor burnouts are stopped if it is dried to, or below 25 ppm.

When cleaning a refrigeration system, there are four basic functions to be carried out -- water removal, acid removal, filtering out of circulating solids, and some means of indicating when the drying job is complete. Driers will do the first three. A moisture indicator is required to do the fourth. Driers should be left permanently in the systems since oil dries out slowly, also cellulose insulation in hermetic compressors may release moisture over a long period of time. A drier is like a sponge, however, and can become saturated and leave the refrigerant still wet if the drier is too small. A moisture indicator is the only sure means of recognizing this situation, especially if it is an air conditioning application with no possibility of freeze-up.

There are various moisture indicators available on the market. A liquid line moisture indicator (Ansul) turns pink when the system is dangerously wet and turns blue when it is safely



20-21. A drier equipped with a sight glass and two moisture indicators. The sight glass will reveal a shortage of refrigerant and will also show a moisture indication for either R-12, or R-22 refrigerant.
(Ansul Chemical Co.)

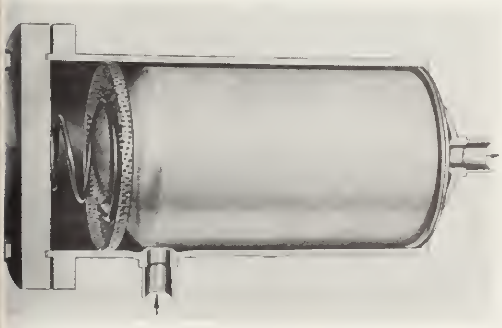
dry. The indicator is under a glass window in the top of the T connector. Figure 20-21.

Another indicator (McIntire), turns purple or orange if dangerous amounts of moisture are present and green if the refrigerant is dry. Figure 17-40.

See Paragraph 17-22 for instructions on drier sizes.

Remember that "Freon-22" driers must be three to five times as large as for an equal quantity of "Freon-12." Driers must be eight times as large for methyl chloride as for the same poundage of "Freon-12." The greater the ability of a refrigerant to hold water, the larger the drier required.

Another type of drier is shown in Figure 20-22. It has a bolted flange on one end to facilitate replacing the desiccant core. The core is a hard cylinder made of a desiccant with an inert binder. Since heat may injure the desiccant, the core should be removed while the joints are being soldered.



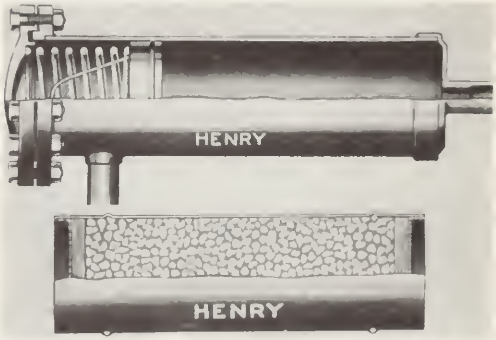
20-22. A large capacity dehydrator with one end removable to enable replacement of the desiccant.
(Sporlan Valve Co.)

Cartridge type driers are also available. One end of the drier is removable and the spent drier cartridge may be replaced. Figure 20-23.

Liquid anti-freezes and so-called liquid dehydrants are available which eliminate freeze ups. These liquids either chemically combine with the water or act as an anti-freeze like alcohol in an automobile radiator. Some manufacturers void their warranties if these liquids are used in their equipment.

Only two things should be inside a refrigeration system. They are clean dry refrigerant and good dry oil. A system which is clean, dry, and acid-free will run indefinitely without corrosion, freeze-ups, oil breakdown or hermetic motor burn-outs. In such a system there is nothing to filter and plugging is impossible. A clean, dry, acid-free system will remain factory bright and trouble free in operation. A normal system is a completely clean one. A dirty system is a faulty system and must be regarded as a mechanical failure, just as much as a faulty valve plate or connecting rod.

The best assurance that a system is dry is to use and depend on a moisture indicator.



20-23. A replaceable cartridge type dryer that has granular desiccant in a special cartridge. A. A replaceable cartridge type dryer. B. A replacement cartridge.
(Henry Valve Co.)

20-43. REFRIGERANT CONTROLS

The installation, operation, and service of refrigerant controls in com-

mercial systems is much the same as described in Chapter 5.

All types of refrigerant controls may be found in commercial systems. If the system is a self-contained open unit or a hermetic unit, it is serviced in a manner similar to that explained in Chapters 11 and 17.

The multiple cooling coil installations however, do have several other features with which a service man should be familiar.

20-44. SERVICING DRY MULTIPLE COILS

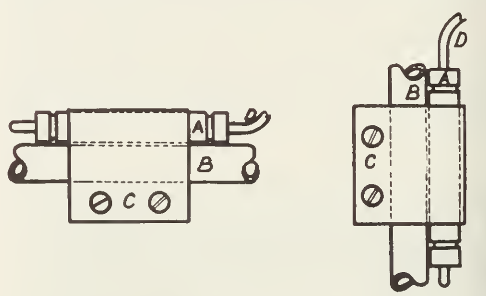
Dry multiple systems which use the thermostatic expansion valve refrigerant control have troubles and the symptoms for these troubles may be similar to the low side float troubles. The same difficulties of servicing are encountered with these coils because of the number of coils connected to one condensing unit.

The service man can check the individual coils by the appearance of the coil, by the sound, and by the temperature of the expansion valve. If the coil is frosting back so the suction line is frosted, it may be due to the following troubles: The needle may be leaking; the control may be adjusted for too high suction pressure; the power element may be attached loosely to the suction line, Fig. 20-24, the power element may be located in too warm a position; moisture may have condensed and frozen on the exterior of the bellows, keeping the needle open; dirt in the system may be holding the valve open.

To determine which of these troubles is the one responsible for the faulty operation is a difficult task, and the best method is a process of elimination. The location of the power element may be easily checked and its attachment to the suction line noted. It is recommended that the thermostatic bulb be placed on top of the suction line rather than beside or below it in order that the liquid in the bulb will make good thermal contact with the suction line. A thermostatic control in which the adjustment has been tampered with is very rare and one may usually depend upon customers not trying to set them; therefore, one should not attempt to readjust the control at first, but rather to check for the other troubles. Leaky needles or out-of-adjustment valves cannot be repaired satisfactorily on the premises.

The service man should remove a faulty expansion valve and replace it with one that is known to be in good condition. The troublesome valve may then be checked in the shop which should be equipped for this purpose and the trouble accurately determined.

If it becomes necessary to dismantle a thermostatic expansion valve, the thermostatic element should be removed as a complete assembly and not taken apart. The thermostatic element is charged with refrigerant and the power element bellows is under considerable pressure at normal temperatures. In the assembled condition



20-24. An illustration showing the location of thermostatic bulbs on suction lines to obtain best operation.

this pressure is counteracted by springs or by expansion valve diaphragm pressure. If dismantled and the power element is free to act the pressure may burst the power element or at least extend it so far that its accuracy is destroyed. If the thermo-

static bulb is placed in an ice and salt solution and its temperature brought low enough, the power element may then be safely dismantled.

A starved coil, that is, one that is giving very poor cabinet temperatures and the coil itself is frosting very unevenly or not sweating properly, may be due to the following:

1. A clogged screen in the expansion valve which may give no refrigeration
2. A loss of refrigerant from the power element in the expansion valve will give erratic refrigeration
3. Moisture in the system which may periodically give good refrigeration and then none, as the moisture will freeze in the orifice to the expansion valve and close it
4. Wax in the valve. This wax is from the oil and its presence means that the oil used was for a different temperature range or was improperly prepared for refrigeration service
5. A stuck-shut needle (although this is a very rare occurrence).

In case of expansion valve trouble it is recommended that a new valve be installed. A clogged screen may be easily detected. The repair is very simple.

Removing an expansion valve which has a clogged screen necessitates removing both the liquid and gaseous refrigerant from the lines to be opened. The liquid line may be carefully heated, driving the liquid refrigerant back to the nearest shut-off valve, and this valve then closed. The coil is already evacuated (indicated by a warm coil); after determining that the low side pressure is at atmospheric pressure or higher, the suction line valve may be closed. The screen may now be removed after cleaning and drying the connections.

Upon assembling the coil after a repair has been made, the air should be removed by purging the coil through a loosened connection at the suction line shut-off valve. The purging may be performed by cracking the suction line valve and removing the air through the expansion valve low side fitting, if the low side pressure of the system is 10 pounds per square inch or more.

In multiple systems all dry coils using expansion valves should be installed with individual shut-off valves for both the liquid and suction lines to each coil.

A condition which results in trouble with thermostatic expansion valves is the attempt to adjust these valves in an effort to maintain too great a difference in temperatures in various boxes in the system. This gives rise to very erratic operation particularly in the coils which are closed off the most. The remedy for this difficulty is to use in addition to the thermostatic expansion valve, one or more two-temperature valves in the suction line in appropriate places.

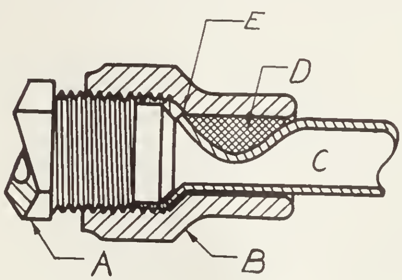
The problem of balancing the pressures in a multiple dry coil installation is very similar to those explained in connection with removing a low side float, Paragraph 20-40. An important factor, inasmuch as most of these systems are Freon -12, is to dry thoroughly all connections before breaking them open. Frequently, the thermostatic expansion valve is attached to the coil in such a manner that this is difficult. It must be done by using a dry cloth or one saturated with alcohol in order to dry thoroughly and prevent future trouble due to moisture and dirt entering the system.

Needless to say, as soon as the expansion valve is removed, the refrigerant openings should be plugged with appropriate fittings.

In multiple commercial installations in which finned coils are used, the expansion valve is usually attached to

the coil by means of an S.A.E. flared connection. The flare nut in such an installation must be shellacked, or sealed from moisture, after the installation has been made and before the unit starts to operate; otherwise, ice will form between the nut and the tubing and in a short time will cause the tube to collapse or break, Fig. 20-25.

Other methods have been devised to prevent moisture from accumulating behind flare nuts. One method provides a rubber seal at the end of the flare nut and another method consists of drilling holes through the flare nut, the idea being that moisture will drain out and if ice does form it will release its pressure through the holes in the nut rather than against the tubing, Fig. 20-26. As mentioned previously, the best sort of connection for use in the interior of the cabinets is a soldered flanged connection. Although soft solder is most popular, some manufacturers are recommending silver brazing for all such joints except for expansion valves as it is stronger and safer.



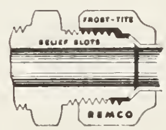
20-25. An illustration of what happens when moisture freezes between the nut and tubing. A. Fitting; B. Flare nut and tubing; D. Ice Formation; E. Flare being pulled of place.

20-45. SERVICING MULTIPLE FLOODED COILS

The repair of flooded coil low side floats is similar to that of the single unit refrigerators discussed in Chapter 11, but locating the trouble and dismantling and assembling of the unit differs somewhat from the single unit practice. Gauges cannot be used to investigate individual coil troubles on multiple installations. Therefore, one must use ordinary observation to determine the trouble.

A continuous hissing sound in the cooling coil is always an indication of coil trouble and may be due to the following causes: (1) A leaky needle, (2) a lack of refrigerant, (3) a float out of calibration, (4) the cooling coil not being level, (5) a leaky float ball.

The hissing sound is very distinctive if there is a lack of refrigerant and, in addition, the liquid line is considerably warmer than the suction line at the



20-26. Showing a method of preventing ice accumulation between a flare nut and the tubing. (Remco Inc.)

cooling coil. This may be determined by putting one's hand over the two lines just as they are going into the cooling coil. The temperature difference will be noted at once. The suction line, although cold, will never frost or sweat if there is a lack of refrigerant. If the needle and seat are leaking, the hissing sound is not so distinctive and may be classified more as a gurgling sound. Also, the suction line will likely frost back to the opening in the cabinet wall and sometimes all the way back to the compressor. This frosting under normal conditions should never be more than 6 in. to 8 in. back along the suction line.

A low side float coil out-of-level may be very easily checked with a spirit level. An out-of-calibration float and a leaky float ball are rather difficult to check and necessitate dis-

mantling the cooling coil to learn the source of the trouble. A float which is calibrated so the refrigerant level is too low when the needle closes will not give the above sound, but will be indicated by a poor frost surface on the coil and inadequate cabinet temperatures. It will tend to become oil bound, since this condition permits an extra deep layer of oil to form on the top of the refrigerant.

In case of a lack of refrigerant, the coil farthest from the condensing unit vertically will be the one to show lack of refrigerant first. Another way to check up as to what trouble is occurring in the coil is to loosen the cooling coil from its hanger and rock it back and forth. If it has an out-of-calibration float or a slight lack of refrigerant, one will be able to hear the hissing sound stop for short periods of time as the liquid refrigerant moves back and forth in the chamber. If there is a leaky needle, the noise will not change. If the needle is leaking, or one of the other troubles is existent, one way to determine it is to shut off the liquid line valve (normally the one mounted right on the cooling coil). Then allow the condensing unit to run for several minutes; this will lower the float more than usual. Next, quickly open the valve, permitting a rush of liquid refrigerant to wash past the orifice opening. If a piece of dirt has lodged between the needle and its seat this will be immediately washed away and the sound of hissing or gurgling will stop momentarily, indicating that the trouble has been eliminated.

To dismantle the cooling coil, in case the necessity arises, the procedure varies depending upon the low side pressure that the unit is operating under. A common servicing policy, if a leaky float needle is discovered, is to close the liquid line valve and leave the coil for a day. During this time the operation of the condensing unit gradually pumps the refrigerant out of the bad coil, and continues to furnish refrigerant for the other cooling coils in the systems. The users of the cabinet should be warned that refrigeration will not be continued until the coil is repaired. After the above period of time, a replacement float mechanism should be installed in the coil. It is not recommended to repair the unit on the job. Nor is it recommended to keep the float chamber open for any length of time. The coil is now all pumped down, and the next operation is to balance the pressures and isolate the coil. As mentioned, the balance depends upon the low side pressures in the system. In many installations this pressure will be found to be very close to atmospheric. If the pressures are atmospheric or above it, the service man simply turns off the nearest suction line valve which will isolate the cooling coil from the rest of the system. After thoroughly cleaning all of the joints and drying them, the unit is ready for dismantling. If the pressures are below atmospheric, the following procedure must be followed. The pressures throughout the low side of the system are the same; therefore, if the unit is running at 5 in. to 15 in. of vacuum, the service man must stop the unit when the compound gauge on the condensing unit reads 0 psi, close the nearest suction line valve, and start the unit again.

There is always a quantity of oil in the low side float coils, and it is important when opening the chambers to guard against any chance of the oil flowing out of the coil. To avoid the possibility of oil escaping, loosen the hanger bolts and tilt the coil so that the front end is lifted. This will eleminate the source of embarrassment. However, this leads to the difficulty of not being able to determine whether or not the cooling coil has too much oil in it. Unless the coil has been showing signs

of oil binding, none of the oil should be removed. A certain amount of oil is required for the correct operation of these units. The exchange of float mechanisms should be done as rapidly as possible and a new gasket should be used. When tightening the cap screws on the cooling unit header, extreme care should be taken to tighten them evenly. The best system to follow in tightening these screws is to skip each alternate screw and go around the header, tightening each screw a little at a time. Only experience can tell how firmly to tighten the screws. As mentioned before, always use cadmium plated or Monel metal cap screws.

20-46. SUCTION LINE

The suction lines have the following items that may need service:

1. Fittings
2. Hand valves
3. Two-temperature valves
4. Pressure reducing valves
5. Surge tanks

The fittings are checked as previously explained and the hand valves are similar in construction to the liquid line hand valves. It is important to check the suction line size and to determine, by using the compound gauge, the pressure drop in the low side of the system. The pressure drop varies but it should not exceed 2 psi. To check the pressure drop, record the low side pressure when the unit is running and then record the pressure just as the unit stops. The difference in the readings is the pressure drop.

20-47. CARE OF SERVICE VALVES

Service valves on commercial installations must be kept in very good condition because they are used much more frequently than those on a domestic unit. Three things may be noted which will assure good service and valve life: (1) fitting the wrench to the valve stem, (2) maintaining the packing so that the service valve will not leak, (3) oil the threads of the gauge connection each time gauges are used. Occasionally after a certain period of use these service valves have to be replaced. After gauges have been mounted in the gauge opening of the valve a number of times, the pipe threads in the valve gauge openings become worn and leak at this point. If the fittings inserted in these gauge openings are given a thin coat of solder, this trouble will be eliminated.

One of the most frequent valve troubles is the breaking of the valve stem because of the stem sticking in the valve body. Most valves are made with a drop-forged brass body and a steel valve stem. If one will heat the service valve with a torch, the difference in expansion qualities of the two metals will loosen the stem from the body and make it easy to turn. If one does this and at the same time taps the valve stem lightly with a hammer, there will be no difficulty in turning the valve stem.

20-48. TWO-TEMPERATURE VALVES

Many multiple installations involve several cabinets of different temperatures connected to one condensing unit. This necessitates the use of two-temperature valves. There are three principle kinds of two-temperature valves as explained in Chapter 19. Each has its definite application. The metering type, two-temperature valve is commonly used in ice cream and soda fountain combinations in which the ice cream must be maintained at around 5 F., the beverage coolers must be kept at about 45 F., and the storage chamber kept at a different temperature.

The two-temperature valves used to permit this condition should be install-

ed in the suction line of the warmer coils. This connection may be at any place on the suction line because its operation is usually not affected by the distance from the coil. Frequently this valve may be found located in the soda fountain, although many are located near the condensing unit.

This type of installation may be improved considerably by mounting a check valve in the suction line of the coldest coil to prevent the backing up of the higher pressure gases into it; also a surge tank should be mounted near the condensing unit and connected between the compressor and the main suction line to cut down the rapid fluctuations of the low side pressure.

In most code installations the two-temperature valve and the check valve must be mounted near the condensing unit, and the surge tank must be mounted on the condensing unit base.

20-49. SERVICING TWO-TEMPERATURE VALVES

As explained in Chapter 19 the two-temperature valves are automatic valves, which, when installed in the suction line, maintain a higher refrigerant pressure on one or more coils than that which exists in the remainder of the system. Three types of two-temperature valves are:

1. The metering type
2. The snap action type
3. The thermostatic type

The metering type, two-temperature valve is the least expensive of the three and is used extensively in a beverage cooling and ice cream cabinet combination. It should be located in the suction line of the beverage cooler and maintains an evaporating pressure in the beverage cooler 10 psi or 15 psi above the pressure needed to maintain ice cream. The four troubles commonly encountered with this valve are:

1. Leaky needle
2. A stuck-shut valve
3. Out-of-adjustment
4. Frost accumulation on the bellows

If the valve is leaky, the beverage cooling coil will be too cold and there will be danger of freezing. This cold temperature may also be due to the two-temperature valve being adjusted too close and at too low a pressure. To determine which of the two troubles is prevalent, a check should be made to see if the valve has been adjusted recently. If the valve has not been tampered with, the trouble is very likely a leaky needle. If the valve has been tampered with, one must readjust it by using a thermometer to obtain the correct beverage coil temperature. The adjusting nut should not be turned more than 1/2 turn at a time. A 15-minute interval should be allowed between each adjustment to permit the coil to completely respond to the new pressure.

For accuracy in making adjustments on two-temperature valves, a low pressure gauge should be installed in the low pressure side of the cooling coil. Sometimes such a gauge opening is available, but in many cases it is not. Service work on such valves will be facilitated if the service man, when installing two-temperature valves, will install a shut-off valve with a gauge opening in the suction line to permit the use of a gauge to check the low side pressure.

A stuck-shut valve, which will be a very rare occurrence, may be easily checked by a non-cooling condition of the beverage cooler and an adequate refrigerant supply to the two-temperature valve, but not through it. This refrigerant supply may be checked by cracking the flare nuts on the high pressure side of the two-temperature valve. Some of these two-temperature valves are provided with screens; a clogged screen will be indicated by a

non-cooling condition of the beverage coil with symptoms similar to the stuck needle condition.

Frost accumulation on the bellows will occur only when the valve is located in or near a freezing compartment. The valve should be removed from the freezing compartment and the bellows covered with vaseline.

Exactly the same troubles are encountered with the snap-action, two-temperature valve as with the metering type. However, most of the snap-action valves are provided with a gauge connection in the nature of a one-way service valve mounted on the two-temperature valve body. This gauge connection makes the adjustment of the valve very simple and is a means whereby one may determine whether the valve is leaking or out of adjustment. Occasionally, trouble is encountered because of presence of moisture and its freezing on the exterior of the valve bellows. This moisture prevents the bellows from working evenly and will tend to give erratic operation to the unit. Any frost accumulation on the bellows should be removed and the bellows coated with vaseline to prevent any further accumulation.

The thermostatic two-temperature valves offer the same troubles, causes, and remedies as the above two and in addition it has troubles resulting from the thermostatic element. These troubles are exactly the same as mentioned in regard to the thermostatic expansion valves. They are:

1. Loss of the charge from the thermostatic element
2. Frost on the bellows
3. Poor power element contact with the coil
4. Pinched capillary tube
5. Wrong adjustment

These troubles are checked in the manner similar to the method of checking the thermostatic element in thermostatic expansion valves.

20-50. SERVICING MOTOR

Motors used on commercial condensing units usually vary in size from 1/2 H.P. to 15 H.P. Air-conditioning systems require motors of 1/3 H.P. to 25 H.P. These motors are connected to either 110-220 volt single-phase or to three-phase lines. The most popular voltage for the medium sized commercial motor is 220 volts single phase.

In addition to the condensing unit motors, commercial systems use motors for fans, water pumps, stir mixes in ice cream machines, etc.

Many localities require that a licensed electrical contractor, remove, repair and install these motors. However, the refrigeration service man must be able to diagnose motor troubles, to be able to locate the fault. It is best for the refrigeration service man to sub-contract the motor work.

Motor troubles can be traced to

1. Mechanical troubles
2. Electrical troubles

Mechanical troubles are those faults in the bearings, pulleys, out of alignment and excessive end play.

Electrical troubles may be further classified as

1. Internal troubles
2. External troubles

To test the motor, it should be disconnected from the compressor and run without any load imposed upon it. The sound of the motor is very indicative of any trouble. Under normal conditions a motor will emit a steady low hum, but in case of worn bearings, rubbing armatures, dry bearings, lack of voltage, etc., erratic beats will be heard in the humming, and the armature may chatter. If one is doubtful as to condition of the motor, it may be thoroughly checked as suggested in Chapter 7.

With the motor running, make sure the armature position is between the two extremes of the armature end play. If the armature operates against one extreme of the end play, it means that it is trying to assume its magnetic center and in not being able to do so is running inefficiently. The end play should never exceed 1/16-in. and may be adjusted by using fiber washers which are obtainable at electrical supply houses.

Adequate lubrication of the motor bearings is absolutely necessary, and the amount of oil in them should be carefully checked. Refrigerant oil should not be used to lubricate motor bearings. Too much oil is just as detrimental as not enough. Most motors are equipped with overflow openings which eliminate most of the danger of too much oil. Bearing temperatures are best checked with a thermometer.

The motor should occasionally be thoroughly cleaned. No dust, dirt, or grease accumulation should be left within the motor or on the exterior of it. Commutators and brushes, if used, should be cleaned. They must make good contact. The brush throw-out mechanism should be free. The brush releasing mechanism of small motors may be checked by mounting a V-belt on the motor pulley and imposing a load on the motor by pulling on the other end of the belt. A torque stand is naturally the best means of determining the real capacity of a motor. See Chapter 12. A noisy motor may be caused by a loose pulley, a loose fan on the pulley, or a loose flywheel. These items should be checked when a noise complaint is received.

Fan motors are usually of the shaded pole type. The most common trouble is worn bearings. The location of these motors usually results in a lack of attention to oiling. Many of these motors are designed to not need lubrication attention but practice has proven that many do need lubrication periodically.

The pump motors and mixer motors are serviced similar to the methods described.

Always be sure the motor is wired correctly, and that the voltage at the motor is sufficient. Always test a motor for grounds, and ground the motor (single phase units).

20-51. MOTOR CONTROL TROUBLES

Three types of motor controls are used in commercial refrigeration, namely, the low side pressure motor control, the thermostatic motor control, and the high side safety motor control. The troubles encountered with these include:

1. Corroded points
2. A broken "Mercoid" bulb
3. Out-of-adjustment
4. Corroded or broken operating springs
5. Out-of-level
6. Leaky bellows

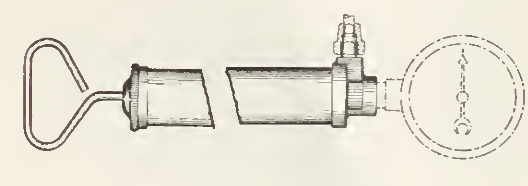
Motor controls normally function year in and year out without giving trouble, but in cases such as unit overloading, the resultant shortcycling will very rapidly deteriorate the contact points in the control, or will so overload the "Mercoid" that it will crack and be destroyed. Corrosion of the points may be remedied by cleaning with very fine sandpaper (emery cloth must not be used) or a fine mill file. A broken Mercoid bulb must be replaced.

An out-of-adjustment switch is often the result of tampering. These causes of trouble are often difficult to overcome. A pressure control may be easily checked by installing the gauge manifold; use the compressor as a vacuum and pressure pump and check the cut-in and cut-out points. Three different methods may be employed to build up a pressure in the crankcase after the

compressor is run to the cut-out point of the control: (1) The suction line may be cracked open again; (2) a by-pass may be run from the discharge service valve of the compressor to the suction service valve (use the gauge manifold); (3) one may use a refrigerant service drum containing the same kind of refrigerant attached to the gauge manifold. Many service men carry a hand vacuum and pressure pump in their tool kit for the purpose of testing controls. Fig. 20-27. This tool enables a rapid check of the pressure control.

A thermostatic motor control is more difficult to reset; the only approved method is to use an ice bath and thermometer. The control may then be set to cut in or out at any temperature desired. See Chapter 12.

The high pressure motor control presents but few difficulties because it is adjusted to work only under extreme conditions. The most common troubles encountered are the occurrence of leaks in the bellows, or at the joints of the controls. Occasionally, however, one will find that this control is short cycling the refrigerating mechanism, and this short cycling is due to excessive head pressure. To check a high pressure motor control element, connect it to the gauge manifold and turn the discharge service valve all the way in. On running the compressor, a head pressure will be produced sufficient to cut-out the control; the high pressure gauge will record the pressure at which the cutting out takes place.



20-27. A hand vacuum pump used for adjusting motor controls.
(Aminco Refrigeration Products Co.)

20-52. PERIODIC INSPECTIONS

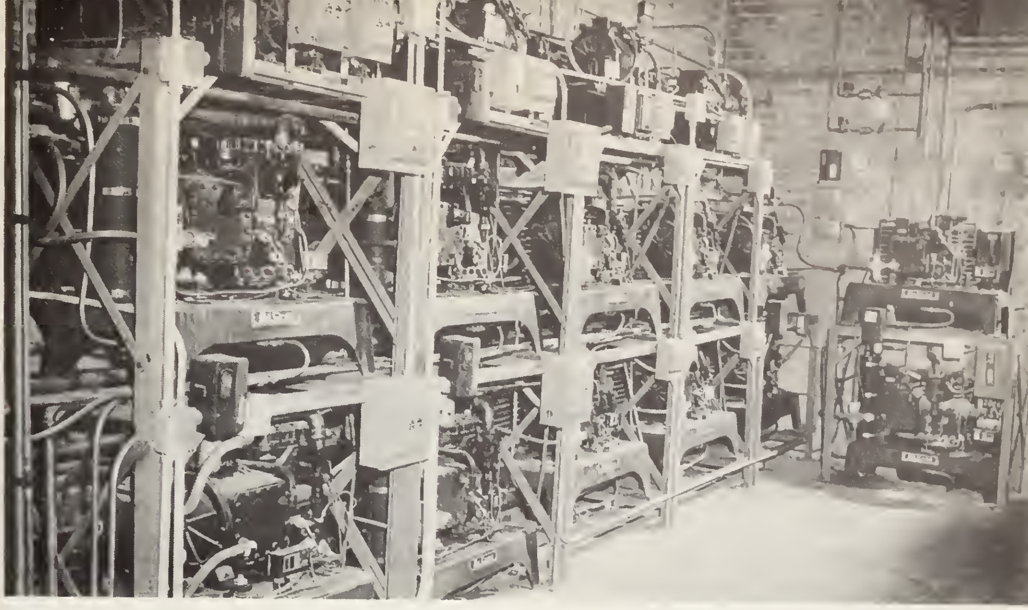
The capital investment in any commercial refrigeration installation represents hundred of dollars. The inherent construction of most mechanisms is such that any troubles in the system will be accumulative; that is, one trouble will cause others. It is, therefore, essential that all commercial machines should be completely checked over periodically. The service man should devise a systematic method of doing this in order that no detail may be overlooked. Inspections should cover such things as:

1. The electrical connections
2. Motor
3. Compressor noises
4. Amount of refrigerant
5. The water flow
6. Gas leaks
7. Coil conditions
8. The supports for the tubing
9. Coil supports
10. The condensing unit operation
11. Oil level
12. Belt condition
13. Belt alignment
14. Belt tightness
15. Cleanliness

It establishes good will and also builds up a good contact file to prepare a check sheet one copy of which should be given to the owner. This check sheet is the only time-tried system that insures that one will not overlook some important item.

20-53. SERVICE RECORDS

Service records are absolutely essential if one wishes to establish a permanent business. These records should contain all details of the ownership, the machine, and what type work was done and material used. This record enables check backs if the unit does not operate correctly, and it



20-28. A condensing unit room or machine room for a super market. The seventeen condensing units are racked on especially built stands. Note the oil separators and variety of units used.

establishes sales prospects as units become older.

20-54. REFRIGERATION SERVICE CONTRACTING

Much has been done during the past few years in respect to contracting for refrigeration service. Many large companies have developed definite policies in this respect, and many of the larger independents are featuring this type of servicing. See Fig. 20-28.

The usual contracting plan provides for a charge of a definite monthly or weekly rate, for which the service company agrees to keep the refrigerating mechanism in good condition. This charge may or may not cover parts depending upon how the contract is written. The success of such a plan depends upon a large volume of contracts in order to break even on extremely bad installations. It is possible that some multiple installation may be completely ruined in a very short time from some very minor trouble; a service contract on such an installation certainly would be unprofitable to the service company, and only a large number of profitable contracts would enable an organization to tide over a situation of this kind. Contracts may be on a time and material basis. Two features of a service contract which appeal to the purchaser are the 24-hour available service clause, and an absolute guarantee of work done.

If one has a service contract, a procedure sheet or record sheet should be used to prove service and to insure complete coverage of checking.

This check sheet should include:

1. Test for leaks
2. Check refrigerant charge
3. Check oil charge
4. Check water valve
5. Check water drain
6. Check and lubricate motor
7. Check belt condition and tension
8. Clean unit

20-55. SERVICE ESTIMATES

Many organizations operating refrigerating equipment ask for bids when a repair, replacement, or service is required. A service organization bidding on such work should have a man who specializes in estimating work of

this kind. This man should be thoroughly acquainted with material costs, service problems, and labor costs; he must be able to judge the time necessary to do the repair. A pleasing personality in combination with rapid and accurate estimating ability is essential.

20-56. REVIEW QUESTIONS

1. Why do code installations require safety release valves on some receivers?
2. Why must hand valves be provided in the refrigerant lines to each individual coil?
3. Why is it necessary to run refrigeration tubing parallel with beams rather than across them?
4. Why is it necessary to mount low side float coils absolutely level?
5. Where are two-temperature valves usually located?
6. Where may soft tubing be used in a code installation?
7. Explain the method whereby air is removed from a multiple dry coil system.
8. Why is it necessary to put a dehydrator on a new system?
9. What would be the purpose of a dehydrator placed in a suction line?
10. Why are hard drawn copper tubing and streamline fittings becoming popular?
11. How is a lack of refrigerant in a low side float multiple installation indicated?
12. What may be wrong if a thermal expansion valve coil suddenly starts to frost excessively at the expansion valve, but the coil near the suction line connection is dry?
13. How are flare nuts protected so moisture cannot get under them and freeze?
14. Why is it necessary to have an open water drain?
15. What must be done to balance the low side pressures in a multiple coil installation in case the system is running on a 5-in. vacuum?
16. Are commercial systems normally charged through the high pressure side or low pressure side?
17. What safety precautions should a service man follow when charging a system through the low side?
18. Why are soldered flanged fittings recommended foruse in making inside cabinet connections?
19. What is the purpose of the felt and fine mesh screen in a dehydrator?
20. Why must a system be very carefully checked for leaks if a lack of refrigerant is discovered in the system?
21. What is the difference between a dehydrator and a neutralizer?
22. What special precautions must be followed when installing a suction line?
23. Why must calcium chloride be kept in a sealed container?
24. What cleaning fluid should be used to clean joints before the joints are opened?
25. What may cause a water-cooled condensing unit to short cycle?

Chapter 21

COMMERCIAL REFRIGERATION CALCULATIONS AND HEAT LOADS

Most commercial refrigeration installations are refrigeration engineering problems. Four steps are required in the solution of a refrigeration installation problem.

a) The total amount of heat (heat load) that must be removed
b) The selection of a condensing unit to handle the heat load
c) The selection of a coil or cooling unit which in connection with the condensing unit will furnish the refrigeration desired
d) The installation of the system, which must consider such factors as water supply, temperature control devices, refrigerator line sizes, air circulation, and humidity control, codes, etc.

In determining heat loads two factors must be considered; these are:

1. Insulation or heat leakage into the box or container. This is affected by the amount of exposed surface, the thickness and kind of insulation, and the temperature difference between the inside and outside of the box.
2. Usage or service in the temperature of the articles put into the refrigerators, their specific heat, generated heat, and latent heat as the requirements demand, also the factors of the nature of the service required such as the number of times per day that the doors of the refrigerator are opened, heat generated inside by fans, lights, and other electrical devices.

The selection of a condensing unit is usually made from manufacturers' tables of capacities. Cooling coils are selected from specifications for capacities, and are selected to balance the capacity of the condensing unit. Also the type of temperature control, the arrangement for air circulation, and specific duty affect the selection of a coil.

The installation of all commercial refrigeration equipment involves technical understanding of all the factors and is a determining factor in the successful operation of the system. The following paragraphs on commercial refrigeration are aimed to lay a foundation on the process of specification and installation of commercial refrigeration equipment.

21-1. HEAT LOAD

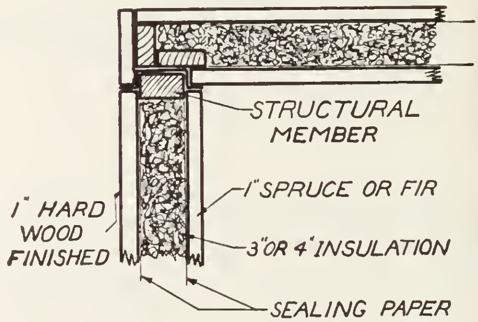
The total heat load consists of the amount of heat to be removed from a cabinet during a certain period. This is dependent on two main factors:

1. The heat leakage load
2. The heat usage or the service load.

21-2. HEAT LEAKAGE VARIABLES

Various research organizations throughout the world have experimented to determine the factors of heat leakage through walls; refrigeration companies have spent considerable time perfecting means whereby we can be absolutely sure of the quantity of heat that leaks into definite kinds of containers for refrigeration. The five factors that affect heat leakage are:

1. The time
2. The temperature difference
3. The thickness of the insulation
4. The kind of insulation
5. The external area of the cabinet
   a) The longer the period of time, the more heat will leak through a certain wall. The standard time unit used for computation is the 24-hour period, although a few prefer the 1-hour period.
   b) The difference in temperature is an important factor in the heat leakage of a container. The greater the temperature difference the more heat will leak through the wall. One might compare this idea to pressure: the more pressure the more gas or water will flow through an opening.
   c) The third variable is the thickness of the insulation. The thicker the insulation, the less heat will flow through it. Twice as much heat will leak through a wall that is insulated with 1 in. of insulation as will flow through a wall having 2 in. of insulation.
   d) The kind of insulation or the material used is one of the most important considerations in the construction of these containers. Cork, for instance, will insulate approximately four times better than wood and eight or nine times better than brick, etc.; on the other hand some insulations are more costly than others and this must be taken into consideration.



21-1. A cross section of a walk-in cooler wall.

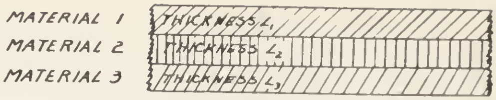
   e) Just as the size of the pipe determines how much water will flow through it (the bigger the pipe the more water will flow), so the more the area through which heat may leak the greater the heat flow. The common unit used for determining heat flow is the square foot of area. This area is always taken as the outside of the container, although to be exactly accurate one should use an intermediate area.

21-3. HEAT LOAD (LEAKAGE)

To bring together the variables just mentioned, standards have been developed and are now being used by the various refrigerating companies. The variables have been reduced to unit values, and the heat leakage of the wall is first determined for the unit values. The unit or basic values are obtained from a slab of the insulation one square foot in area, one inch thick, with a temperature difference of 1 F., and over a

period of time of either 1 hour or 24 hours. The values obtained represent the heat flow through the slab under these conditions and naturally vary with the kind of insulation. This material has no air film or liquid film on either side (enclosed in metal).

This formula deals with one kind of insulation only, in order to compute the heat leakage through a composite wall, such as a wall made out of wood and cork or wood and metal, Fig. 21-1, the formula for computing the common K factor is shown and explained as follows:



21-2. A composite insulating panel.

If the wall is made up of three different materials this overall heat leakage (K) (See Figure 21-2) is found as follows:

The total heat conductivity for the composite structure shown in Fig. 21-2 equals:

$$K = \frac{1}{\dfrac{\text{thickness of material 1}}{\text{Conductivity factor per material 1}} + \dfrac{\text{thickness of material 2}}{\text{conductivity factor for material 2}} + \dfrac{\text{thickness of material 3}}{\text{conductivity factor for material 3}}}$$

df L_1 = thickness of material 1
L_2 = thickness of material 2
L_3 = thickness of material 3

and k_1 = conductivity factor for material 1
k_2 = conductivity factor for material 2
k_3 = conductivity factor for material 3

then the formula becomes

$$K = \frac{1}{\dfrac{L_1}{k_1} + \dfrac{L_2}{k_2} + \dfrac{L_3}{k_3}}$$

To solve for the conductivity for the panel shown in Figure 21-3 proceed as follows:

$$K = \frac{1}{\dfrac{\text{thickness A}}{\text{k for wood}} + \dfrac{\text{thickness B}}{\text{k for Celotex}} + \dfrac{\text{thickness C}}{\text{k for cork board}}}$$

From paragraph 29-10 we find the k values as follows:

k for wood = .80
k for celotex = .31
k for cork board = .285

Substituting these values in the above formula we have

$$= \frac{1}{\dfrac{.5}{.80} + \dfrac{.25}{.31} + \dfrac{.25}{.285}} = \frac{1}{.624 + .807 + .877} = \frac{1}{2.3}$$

= .435 which is the unit of conductivity for the panel.

An air film that clings to the outer and inner surfaces of the cabinet adds to the insulating value of the walls of the cabinet. This added resistance is calculated as in the following formula in which the outside air film is considered to have a heat transfer value of 6.00 and the inside wall air film has a value of 1.65.

K = Unit of conductivity for materials of a composite nature.
U = Unit of conductivity for materials of a composite nature plus the effect of the air clinging to both the outside (F.) and the inside (F.) walls.

If the insulating value of the air clinging to the walls is condensed the formula becomes:

$$U = \frac{1}{\frac{1}{f_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3} + \frac{1}{f_i}}$$

the value of $f_o = 6.0$
the value of $f_i = 1.65$

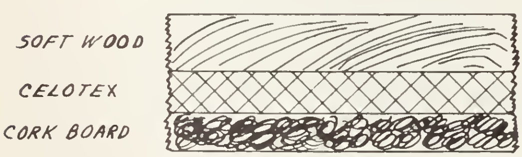
Regarding working the problem in Fig. 21-3:

$$U = \frac{1}{\frac{1}{6.0} + \frac{.5}{.80} + \frac{.25}{.31} + \frac{25}{.285} + \frac{1}{1.65}} = \frac{1}{1.66 + .624 + .807 + .877 + .606}$$

$$= \frac{1}{4.55} = .22$$

The value of K as computed in the previous problem = .435. The value of U as computed in this problem = .22. This shows the insulating value of the air adjacent to both the inside and outside walls.

This type of computation is very complicated as one can readily see; therefore standard tables for computing heat leakage have been developed.



21-3. A composite insulating panel composed of various materials at specified thicknesses.

21-4. TABULAR METHODS OF DETERMINING HEAT LEAKAGE

A method for determining the heat leakage into a cabinet, such as used by some refrigeration manufacturers, is shown by Fig. 21-4. The values are based on actual experiments and investigations, and practice has shown their accuracy.

One will note that tables for the heat leakage of glass are included in Fig. 21-5. Many refrigerator cabinets are equipped with windows. The tables show that the heat leakage through windows is very high compared to the leakage through walls.

To use the tables, proceed as follows (using a butcher or walk-in refrigerator box as a sample problem): The sales engineer visits the establishment and obtains all the data possible concerning the cabinet and the service.

Temperature Difference in Degrees Fahrenheit	Insulation Thickness (Cork or Its Equivalent)				Glass	
	2½ in.	3 in.	3½ in.	4 in.	Double Thickness	Triple Thickness
40°	84.0	72.0	64.0	60.0	440.0	280.0
50°	105.0	90.0	80.0	75.0	550.0	350.0
60°	126.0	108.0	96.0	90.0	660.0	420.0
70°	147.0	126.0	112.0	105.0	770.0	490.0
80°	168.0	144.0	128.0	120.0	880.0	560.0
90°	189.0	162.0	144.0	135.0	990.0	630.0

These tables are based on the use of a layer of wood, both inside and outside of the cork. If wood is not used on both sides, consider that the insulation is one-half inch less than the actual thickness.

21-4. Heat leakage values through refrigerator wall in Btu per sq. ft. per 24 hrs.
(Fedders-Quigan Mfg. Co.)

Temperature Difference in Degrees Fahrenheit	Use of Refrigerator			
	Florist	Grocery or Normal Market	Market with Heavier Service or Freshly Killed Meats	Restaurant Short Order
40°	40.0	65.0	95.0	120.0
50°	50.0	80.0	120.0	150.0
60°	60.0	95.0	145.0	180.0
70°	70.0	114.0	167.0	210.0
80°	80.0	130.0	190.0	240.0
90°	90.0	146.0	214.0	270.0

21-5. A heat usage table Btu/cu ft/24 hrs.
(Fedders-Quigan Mfg. Co.)

For instance, he must determine the exterior dimensions of the box, the dimensions of the windows, the dimensions of the wall, the thickness of the insulation, the kind of insulation, the number of panes in the windows, how much business the butcher does, what temperatures the butcher desires in the cabinet, and what the average summer temperature is for the locality, and also the highest possible water temperature if a water-cooled installation is to be made.

Specification or data sheets are available that help the sales engineer obtain all the data needed to select the proper equipment. Fig. 21-6, is a sample of this type of data sheet.

21-5. CABINET AREAS

With this data he may calculate the following: the exterior dimensions of the cabinet (the width and the length are multiplied together and then multiplied by two; these areas represent the floor and the ceiling of the box; the width and the height are then multiplied together, and multiplied by two to determine the area of the ends of the box; the length and the height are multiplied by two to determine the area of the ends of the box; the length and the height are multiplied together, and then multiplied by two to take care of the sides of the box). Add the three values obtained and the total external area of the box is obtained. By formula:

L Length W Width H Height

(1) W x L x 2 = Area of top and bottom
(2) W x H x 2 = Area of ends
(3) L x H x 2 = Area of sides
Total external area = Sum

The reason most companies base their computations on the external area of the box rather than the interior area or a medium area is that the results are on the safe side. Also this method compensates somewhat for breaks in

REFRIGERATION SALES ENGINEERS DATA SHEET

Name____________________ Type of Business____________ Date______

Address________________City______________Zone____State______

Person Contacted______________________Title______________

Fixture #1-Make________Fixture #2-Make________Fixture #2-Make________

Use_______Model_____Use_______Model______Use_______Model_____

Width__________ ______________ ______________

Length__________ ______________ ______________

Height__________ ______________ ______________

Construction_______ ______________ ______________

Installation:

Kind__________ ______________ ______________

Thickness_______ ______________ ______________

Glass:

Area__________ ______________ ______________

No. of Thickness____ ______________ ______________

Produce__________ ______________ ______________

Light__________ ______________ ______________

Motors__________ ______________ ______________

Location__________ ______________ ______________

Unusual Temperatures____ ______________ ______________

Unusual Service______ ______________ ______________

Salesman____________________

21-6. A sample data sheet which may be used by sales engineers in recording data for a refrigeration installation.

Box	8' HIGH	CAPACITY (CU. FT.)							10' HIGH	CAPACITY (CU. FT.)						
Lg. & Wd.	Outside Sq. Ft.	2" Cork	2½" Cork	3" Cork	4" Cork	5" Cork	6" Cork	8" Cork	Outside Sq. Ft.	2" Cork	2½" Cork	3" Cork	4" Cork	5" Cork	6" Cork	8" Cork
5x 5	210	137	131	124	112	101	90	71	250	174	167	159	144	131	117	93
5x 6	236	169	161	154	140	127	114	91	280	215	206	197	180	164	148	120
5x 7	262	201	194	184	168	153	138	111	310	256	248	236	216	198	179	146
5x 8	288	233	224	214	196	179	162	131	340	296	286	274	252	232	210	172
6x 6	264	209	201	193	175	160	145	119	312	266	256	247	225	207	188	156
6x 7	292	248	238	228	210	193	176	146	344	316	304	292	270	249	228	192
6x 8	320	286	277	267	245	226	207	173	376	364	353	342	315	292	269	228
6x 9	348	325	315	305	280	259	238	200	408	414	402	390	360	335	309	263
6x10	376	364	353	343	315	292	269	227	440	463	451	439	405	378	350	299
6x12	432	444	432	419	385	358	331	281	504	555	546	536	495	463	430	370
7x 7	322	294	283	272	254	234	214	180	378	374	361	348	326	302	278	237
7x 8	352	341	329	317	294	273	252	214	412	434	420	406	378	353	328	281
7x 9	382	386	374	362	334	312	290	248	446	492	477	463	430	403	377	326
7x10	412	433	420	407	374	346	318	282	480	551	536	521	481	448	413	371
7x12	472	527	512	497	454	414	374	348	548	670	653	635	583	535	486	458
8x 8	384	394	382	369	343	320	296	253	448	501	487	473	441	413	385	333
8x 9	416	448	434	420	392	367	341	294	484	570	553	538	504	474	443	386
8x10	448	503	587	471	441	413	385	335	520	641	748	603	567	534	500	441
8x12	512	610	591	573	539	506	473	417	592	776	755	734	692	653	615	548
8x14	576	718	697	675	637	594	561	499	664	914	889	864	818	768	730	656
9x 9	450	510	489	469	448	420	392	341	522	649	623	600	576	543	510	449
9x10	484	570	554	537	504	473	443	386	560	725	706	686	647	612	575	508
9x12	552	694	674	654	616	581	545	476	636	883	859	836	792	752	708	626
9x14	620	814	793	771	728	687	647	566	712	1035	1011	987	935	888	840	745
10x10	520	638	620	602	567	534	500	440	600	870	790	770	729	680	650	579
10x12	592	776	755	734	693	655	617	547	680	988	962	939	890	847	802	720
10x14	664	912	889	866	818	775	733	654	760	1158	1132	1110	1050	1005	954	860
12x12	672	946	919	893	848	804	760	680	768	1203	1172	1144	1090	1038	988	895
12x14	752	1110	1086	1052	1001	951	900	809	856	1411	1382	1348	1289	1230	1170	1060
14x14	840	1304	1269	1235	1180	1126	1072	968	952	1660	1619	1568	1518	1458	1394	1272

21-7. A table of cabinet external areas and internal volumes (capacity). (Bush Mfg. Co.)

the insulation due to the construction of the cabinet. Likewise, these cabinets often have wood corners and wood beams along the walls to reinforce the paneling and this wood is not as good an insulator.

Tables can be used to obtain the external area of a cabinet and also its internal volume. Fig. 21-7.

After obtaining the external area of the box, one must subtract the window area to obtain the true area of the insulated surface. Window areas are calculated from the measurements of the outside edges of the window frame and must be considered separately.

The total external area -- the window area = the insulated area.

From the table (Fig. 21-4) one may find the amount of heat that will leak through the insulation per square foot of area per 24 hours for that particular type of wall construction. For example, if the wall is made of 1 in. lumber paneling on both sides and 3 in. of slab cork between, the tables will reveal that at a temperature difference of 50 F., (85 F.-35 F.) 90 Btu will leak through per square foot during the period of 24 hours. The glass leakage table will similarly give values for the heat leakage through 1 square foot of glass. Adding the two will give the total heat leakage into the cabinet.

A typical example is a 6 feet x 7 feet x 10 feet walk-in cooler with two windows 1 1/2 feet x 2 feet. The box is kept at 36 F. in a room with an average temperature of 86 F. The wall construction consists of 3 in. cork with 1 in. lumber on each side. The windows are of the double-pane construction. The temperature difference is 86-36 = 50F.

Solution.

Total surface

Walls: 6x7x2 = 84 sq. ft. (ceiling and floor)

6x10x2=120 sq. ft. (ends)

7x10x2=140 sq. ft. (sides)

344 sq. ft. total area

Windows: 1 1/2x2x2=6 sq. ft. of window
344-6=338 sq. ft. of insulated wall

From table Fig. 21-4,
1 sq. ft. of the wall allows 90 Btu per 24 hours.
90x338 sq. ft.=30, 420 Btu per 24 hours through the walls.

From table Fig. 21-4,
1 sq. ft. of the windows allows 550 Btu per 24 hours.
550x6 sq. ft.=3,330 Btu. per 24 hours through the windows.
30, 420 + 3,300=33,720 Btu Total per 24 hours.

21-6. HEAT LOADS (USAGE)

The total heat load of the refrigerator cabinet in addition to being dependent upon the heat leaking through the walls and windows is also affected by the heat to be removed from articles in the cabinet and air change. This heat is called the heat usage, or the service load, and it is caused by the changes of air in the cabinet, by the produce to be cooled, by lights and motors which may be used inside the box, and by the occupancy of the box.

Refrigeration equipment manufacturers have developed a standard whereby one may obtain a fairly accurate estimate of the usage heat load. The method is as follows: The box is classified as to the type of service to be performed, and under this classification come florist's cabinets, grocery boxes, normal market coolers, fresh meat cabinets, and restaurant short-order boxes. From experience these companies have found that such boxes used for the same general line of business hold rather consistently to the same usage heat load. This load depends in detail upon the following basic factors:

1. The temperature difference between the exterior and the interior of the cabinet
2. The volume of the cabinet (internal)
3. The type of service
4. The time

It is possible to calculate by using a typical installation and determine the amount of food put into the refrigerator, how many times the door is opened, and for how long a period of time the employees are inside the cabinet. This is a very laborious process and, unless very carefully performed, discrepancies are bound to appear in the results.

As the data in the tables are based upon 1 cubic foot content at various temperature differences, so the following method is the usual procedure to determine the usage heat load: The temperature difference is the same value as that used for the heat leakage into this cabinet, while the volume of the cabinet is computed from the inside dimensions. We next determine under what type of cabinet the box may be classified. A meat market, for instance, may be one in either a small residential neighborhood or it may be a central meat market. There would, of course, be considerable variation in the amount of heat to be removed from the contents of these cabinets. The values given in Figure 21-5 can only give the load for certain set conditions and it is necessary to understand the individual case.

After the total volume of the box has been calculated, one must determine the load for each cubic foot by referring to the table; if the cabinet appears to be a normal market with a temperature difference of 50 F., the amount of heat to be removed from each cubic foot will be 80 Btu per 24 hours. Multiply this value by the total volume in cubic feet and a fairly accurate estimate of the service load will be obtained. The table gives the heat usage over a period of 24 hours as this time is the established standard.

Heat usage = usage Btu x volume in cu. ft.

Using the above example:

In the sample cabinet which is 6 x 7 x 10 the walls are 5 in. thick (1 inch wood+3 in. insulation+1 in. wood). Therefore the internal or inside width is 6 feet minus 5 inches minus 5 inches (there is a wall at each end). The inside dimension then equals 6 feet minus 10 inches 6 ft. minus $\frac{5}{6}$ ft. 5 1/6 feet. The same method is used to calculate the other internal dimensions.

The internal dimensions are:

5 1/6 ft. x 6 1/6 ft. x 9 1/6 ft.

$$5\frac{1}{6} \times 6\frac{1}{6} \times 9\frac{1}{6}$$

$$\frac{5 \times 6 + 1}{6} \times \frac{6 \times 6 + 1}{6} \times \frac{9 \times 6 + 1}{6}$$

$$\frac{30}{6} + \frac{1}{6} \times \frac{36}{6} + \frac{1}{6} \times \frac{54}{6} + \frac{1}{6}$$

The internal volume $\frac{31}{6} \times \frac{37}{6} \times \frac{55}{6} =$

$\frac{63085}{216} = 292$ cu. ft.

Heat usage under the above conditions = 80 Btu. per 24 hrs. for 1 cu. ft.

Heat usage = 292 cu. ft. x 80 Btu. per cu. ft. = 23,360 Btu per 24 hrs.

Total Heat Load = Heat leakage + usage = 33,720 (See Paragraph 21-5) + 23,360 = 57,080 Btu. per 24 hrs.

The addition of the heat leakage and usage will give the total heat load upon the cabinet for a certain set period of time. This value may be listed either as Btu's per 24 hours, or Btu's per 1 hour.

21-7. ICE MELTING METHOD

Another way of calculating the total heat load of a cabinet is to use ice as the determining medium. If one were to put an ice bunker in the refrigerator cabinet under investigation in such a manner that the ice would be utilized scientifically, the number of pounds of ice melting per day to produce satisfactory refrigeration will be a measure of the total heat load on the cabinet. The conversion factor between Btu's and ice melting equivalent is 144, meaning that one may divide the Btu's per hour by 144 and the ice melting equivalent value in pounds will be obtained. This I.M.E. value is another standardized means of comparing capacities.

It may be noted that the accuracy of this type of calculation depends upon the original data and also one should be careful in selecting the tables to be used. The tables in this text have been developed through years of careful investigation and are generally considered satisfactory.

Example: What will be the I.M.E. for the cabinet in Paragraph 21-6. The total heat load was 57,080 Btu per 24 hours.

The I.M.E. $= \frac{\text{total heat load}}{144} = \frac{57,080}{144} =$ 396 lbs.

The ice consumed may be measured by collecting the drainage as the ice melts. Two discrepancies that may occur in this method are that the cabinet may require temperatures other than those obtainable by means of ice, and the moisture precipitated out of the air will affect the calculations somewhat. It is also inconvenient in certain cases to put ice into the cabinet to determine the load. Where an installation of automatic refrigeration is to be made in an old ice-cooled box, this method can be used very easily as the ice equipment is already available. The total amount of water drainage does not have to be measured. The most popular way is to measure the drainage for 1/2-hour periods at four intervals during the 24-hour period.

The values are given in pounds of ice melting equivalent per day per 1 F. per 1 square foot of external area. These columns, therefore, base the

usage and service upon the area of the cabinet rather than upon the internal volume. See Fig. 21-8. These companies do not differ radically from the method previously explained in doing this because cabinet designs are such that their volume varies almost directly as the area. For example, two cabinets which have the same exterior area seldom differ much in their cubical contents.

21-8. COOLING COIL AND CONDENSING UNIT CAPACITIES

After calculating the heat load, it is necessary to determine the size of cooling coil and condensing unit required to furnish the refrigeration.

Some important features are as follows:

1. The cooling coil removes heat from the cabinet only when the condensing unit is running
2. The refrigerating unit usually 'runs from 14 to 20 hours out of each 24 hours. This means that the unit must have a refrigerating capacity in 14 hours of operation equal to the total heat load in 24 hours.

The cooling coil's capacity depends upon three conditions:

Type of Usage	Factor-Lbs. of ice per hr. per°F per sq.ft.
Light....	.028
Average..	.042
Heavy....	.056

21-8. Usage factor based on type of service. The refrigeration factor is in points of ice melting effect (I M E) per hr. per degree F per square foot of cabinet surface. (American Society of Refrigerating Engineers)

1. The cabinet temperature
2. The refrigerant temperature
3. The space allowed for the coil

Condensing Unit		Cooling Coil	
Low Side Temp.	Btu/hr.	Temp.Diff.	Btu/hr.
40	6650	0F	300
35	6100	1°	3000
30	5600	10°	4000
25	5100	15°	5000
20	4650	20°	6000
15	4200	25°	7500
10	3800		
5	3400		
0	3000		
-5	2600		
-10	2250		
-15	1900		
-20	1550		
-25	1250		
-30	950		

300 sq. ft. surface natural convection cooling coil.

90°F ambient air

Add 6% for 10°F drop in air temperature, substract 6% for each 10°F rise in ambient temperature.

Liquid Line 1/4"
Suction Line 5/8"
Approximately one H.P.

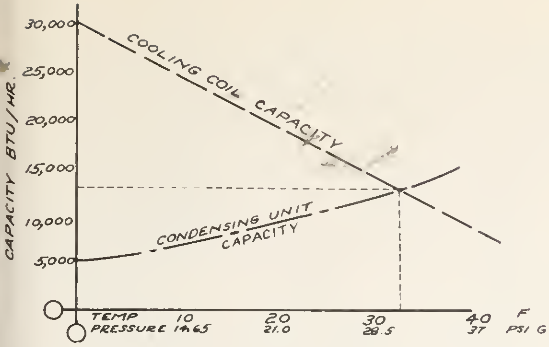
21-9. Tables of condensing unit and cooling coil capacity variations with temperature and pressure.

The condensing unit's capacity depends upon:

1. The low-side pressure
2. The condensing medium

It is more important to balance the capacity of the cooling coil to the capacity of the condensing unit than to the heat load of the cabinet. When balancing the capacity of the condensing unit and the cooling coil, all calculations for each must be based on the same low-side pressure. This is because the capacity of the cooling coil increases as the temperature decreases, while the condensing unit's capacity decreases as the low-side pressure decreases, Fig. 21-9.

The capacity of a cooling unit increases as the cooling coil temperature drops (as the low side pressure de-



21-10. A graph showing the relative effect on cooling coil and unit capacity at different temperatures inside the cooling coil.

creases) providing the cabinet temperature stays the same.

The capacity of a condensing unit increases as the low side pressure increases, Fig. 21-10.

From the figure you see that this particular cooling unit matches the condensing unit at a low side pressure of 32 psi and the combination will remove 12,500 Btu per hour.

To obtain the Btu/hour load on the condensing unit and the cooling coil, one may use the tables in Fig. 21-11 through Fig. 21-15. The tables give directly the capacity of the condensing unit and cooling coil needed to handle the refrigeration load.

As the size of the cabinet becomes larger, simple tables are not accurate enough. The heat leakage factors remaining, the same but the usage factor must be more accurately determined.

Inches Cork	TEMP. DIFFERENCE						
	40°	50°	55°	60°	70°	80°	90°
2″	7.5	9.4	10.3	11.3	13.1	15.0	16.9
2½″	6.3	7.8	8.6	9.4	10.9	12.5	14.1
3″	5.3	6.6	7.2	7.9	9.2	10.5	11.8
4″	4.3	5.3	5.9	6.4	7.4	8.5	9.6
5″	3.5	4.4	4.8	5.3	6.1	7.0	7.9
6″	3.0	3.8	4.1	4.5	5.3	6.0	6.8
7″	2.6	3.3	3.6	3.9	4.6	5.3	5.9
8″	2.3	2.8	3.1	3.4	3.9	4.5	5.1

21-11. A leakage factor table that will give results in Btu per 16 hrs. capacity of condensing unit and cooling coil needed to balance the heat leakage. (Bush Mfg. Co.)

The more accurate calculations on usage determines the air change load and the product load separately.

To determine the leakage load use Figures 21-11 and 21-13.

The air change load is calculated based on the table in Fig. 21-14.

The product load is determined by knowing the amount of the product used per day and the temperature change the product passes through, Fig. 21-15. The table is a complete listing of the most common foods with enough data to enable one to determine the product load under practically any condition.

The use of these three tables can be illustrated by the following problem.

If a cabinet 16' x 20' x 10' with 4 in. cork insulation is in a 90 F. room, and it cools 2000 pound of beef from 60 F. to 35 F. each day, what is the total load?

Heat Leakage 1360 x 102 = 138.720 Btu. per day

Air Change 2760 wft. x 30 = 30 = 82,950 Btu. per day

Product Load 2000 pds x .77 spec. heat x 25 F. temp. diff. = 38,500 Btu. per day

260,170 Btu. per day

Therefore, $\frac{260,170}{16 \text{ hr.}} = 16,261$ Btu per hour based on 16 hours of unit operation.

The manufacturers of cooling coils and condensers list the capacities of their products in Btu's or I.M.E. for either one hour of operation or 16 hours of operation. Before making a choice of models, it is very important that the above items be considered carefully.

21-9. BAFFLE DESIGN

Practically all refrigerator cabinets are now built to be used with mechanical refrigeration. These latter cabinets are specially designed to facilitate cooling of the cabinet with cooling coils. However, old cabinets originally designed for use with ice are sometimes converted into mechanically

Capacity Cu. Ft.	40° T.D.		50° T.D.		55° T.D.		60° T.D.		70° T.D.		80° T.D.		90° T.D.	
	*	†	*	†	*	†	*	†	*	†	*	†	*	†
1-50	6.3	8.3	7.8	10.3	8.6	11.4	9.4	12.4	11.0	14.5	12.5	16.5	14.1	18.6
51-100	5.5	7.5	6.9	9.4	7.6	10.3	8.3	11.3	9.6	13.1	11.0	15.0	12.4	16.9
101-250	4.8	6.8	5.9	8.5	6.5	9.3	7.1	10.1	8.3	11.8	9.5	13.5	10.7	15.2
251-500	4.3	6.0	5.3	7.5	5.8	8.3	6.4	9.0	7.4	10.5	8.5	12.0	9.6	13.5
501-1000	3.8	5.5	4.7	6.9	5.2	7.6	5.6	8.3	6.6	9.6	7.5	11.0	8.4	12.4
1001-1500	3.5	5.3	4.4	6.6	4.8	7.2	5.3	7.9	6.1	9.2	7.0	10.5	7.9	11.8

*Normal †Heavy

21-12. The usage factors that gives the refrigerating unit capacity, Btu per 16 hrs. needed to handle the usage load. (Bush Mfg. Co.)

Leakage Factor Btu's Per 24 Hrs.,Per Sq.Ft.

Inches Cork	40° T.D.	45° T.D.	50° T.D.	55° T.D.	60° T.D.	70° T.D.	80° T.D.	90° T.D.	100° T.D.	110° T.D.
2	120	135	150	165	180	210	240	270	300	330
2½	100	113	125	138	150	175	200	225	250	275
3	84	95	105	116	126	147	168	189	210	230
4	68	77	85	94	102	119	136	153	170	187
5	56	63	70	77	84	98	112	126	140	154
6	48	54	60	66	72	84	96	108	120	132
7	42	47	53	58	63	74	84	95	106	116
8	36	41	45	50	54	63	72	81	90	100

21-13. A table of heat leakage values for large refrigerator cabinets. (Bush Mfg. Co.)

refrigerated cabinets. This necessitates some minor construction changes in the cabinet to permit the use of coils instead of ice. Also the refrigeration service engineer should know the theory of air circulation in the box, and what is supposed to happen during the operation of the unit. The following deals with the study of efficient baffling and correct air circulation in cabinets.

Baffles are surfaces, or air ducts, which increase the efficiency of the air flow around the coil and throughout the cabinet. They direct the air flow in such a manner that it is speeded up and carried all around the interior of the box, leaving no dead or warm air spots, Fig. 21-16. The colder air coming from the coil is made to flow down the center of the box or adjacent to the wall not provided with windows, while the warmer air is directed through other flues back to the coil. The design must be scientifically proportioned to insure that the air circulation is unrestricted and that there will be

Air Change Load B.T.U. Per 24 Hrs. Per Cu.Ft.

Box Capacity Cu. Ft.	40° T.D.	45° T.D.	50° T.D.	55° T.D.	60° T.D.	70° T.D.	80° T.D.	90° T.D.	100° T.D.	110° T.D.
500-1000	36	41	45	50	54	63	72	81	90	99
1001-1500	28	32	35	39	42	49	56	63	70	77
1501-3000	20	23	25	28	30	35	40	45	50	55
3001-5000	16	18	20	22	24	28	32	36	40	44
5001-10000	10	11	13	14	15	18	20	23	25	28
10001-25000	8	9	10	11	12	14	16	18	20	22

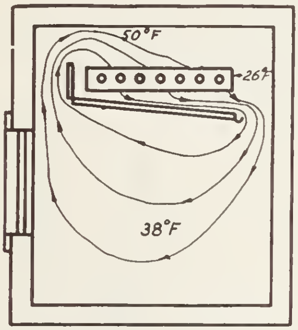
21-14. The heat to remove from the air due to the air changes in large cabinets. (Bush Mfg. Co.)

Product	Quick Freeze Temp.	Storage Temp. Long	Storage Temp. Short	Humidity % R.H.	Specific Heat Above Freezing	Specific Heat Below Freezing	Latent Heat	Freezing Point	Respiration BTU/lb. Per Day
Apples	—15	30-32	38-42	85-88	0.92	0.39	91.5	28.4	0.75
Asparagus	—30	32	40	85-90	0.95	0.44	134.0	29.8	....
Bacon, Fresh		0-5	36-40	80	0.55	0.31	30.0	25.0	....
Bananas		56-72	56-72	85-95	0.81	....	108.0	30.2	4.18
Beans, Green		32-34	40-45	85-90	0.92	0.47	128	29.7	3.3
Beans, Dried		36-40	50-60	70	0.30	0.237	18	....	....
Beef, Fresh, Fat	—15	30-32	38-42	84	0.60	0.35	79	....	....
Beef, Fresh Lean	—15	30-32	38-42	85	0.77	0.40	100	....	....
Beets, Topped		32-35	45-50	95-98	0.90	....	....	26.9	2.0
Blackberries	—15	31-32	42-45	80-85	0.89	0.46	125	28.9	....
Broccoli		32-35	40-45	90-95	0.93	....	....	29.2	....
Butter	+15	....	40-45	....	0.64	0.34	15	15.0	....
Cabbage	—30	32	45	90-95	0.93	0.47	130	31.2	....
Carrots, Topped	—30	32	40-45	95-98	0.87	0.45	120	29.6	1.73
Cauliflower		32	40-45	85-90	0.90	....	....	30.1	....
Celery	—30	31-32	45-50	90-95	0.95	0.48	135	29.7	2.27
Cheese	+15	32-38	39-45	....	0.70	....	....	....	....
Cherries		31-32	40	80-85	0.85	....	118	28.0	6.6
Chocolate Coatings		45-50	....	....	0.3	....	....	....	....
Corn, Green		31-32	45	85-90	0.86	....	....	29.0	4.1
Cranberries		36-40	40-45	85-90	0.91	....	....	27.3	....
Cream		34	40-45	....	0.88	0.37	84	....	....
Cucumbers		45-50	45-50	80-85	0.93	....	....	30.5	....
Dates, Cured		28	55-60	50-60	0.83	0.44	104	....	....
Eggs, Fresh	—10	30-31	38-45	....	0.76	0.40	98	31.0	....
Eggplants		45-50	46-50	85-90	0.88	....	....	30.4	....
Flowers		35-40	....	85-90	....	....	....	....	....
Fish, Fresh, Iced	—15	25	25-30	....	0.82	0.41	105	30.0	....
Fish, Dried		30-40	....	60-70	0.56	0.34	65	....	....
Furs		32-34	40-42	40-60	....	....	....	....	....
Furs, To Shock		15	15						
Grapefruit		32	32	85-90	0.92	....	111	28.4	0.5
Grapes		30-32	35-40	80-85	0.92	....	111	27.0	0.5
Ham, Fresh		28	36-40	80	0.68	0.38	87	....	....
Honey		31-32	45-50	....	0.35	0.26	26	....	....
Ice Cream	—20	....	0-10	....	.5-.8	0.45	96	....	....
Lard		32-34	40-45	80	0.52	0.31	90	....	....
Lemons		55-58	....	80-85	0.91	0.39	190	28.1	0.4
Lettuce		32	45	90-95	0.90	....	....	31.2	8.0
Liver, Fresh		32-34	36-38	83	0.72	0.42	94	....	....
Lobster, Boiled		25	36-40	....	0.81	0.42	105	....	....
Maple Syrup		31-32	45	....	0.24	0.215	7.0	....	....
Meat, Brined		31-32	40-45	....	0.75	0.36	75.0	....	....
Melons		34-40	40-45	75-85	0.92	0.35	115	28.5	1.0
Milk		34-36	40-45	....	0.92	0.46	124	31.0	....
Mushrooms		32-35	55-60	80-85	0.90	....	....	30.2	....
Mutton		32-34	34-42	82	0.81	0.39	96	29.0	....
Nut Meats		32-50	35-40	65-75	0.30	0.24	14	20.0	....
Oleomargarine		34-36	....	....	0.65	0.34	35	15.0	....
Onions		32	50-60	70-75	0.91	0.46	120	30.1	1.0
Oranges		32-34	50	85-90	0.89	0.40	91.0	27.9	0.7
Oysters		....	32-35	....	0.85	0.45	120.0	....	....
Parsnips	—30	32-34	34-40	90-95	0.82	0.45	120.0	28.9	....
Peaches, Fresh		31-32	50	85-90	0.92	0.42	110	29.4	1.0
Pears, Fresh		29-31	40	85-90	0.90	0.43	106	28.0	6.6
Peas, Green		32	40-45	85-90	0.80	0.42	108	30.0	....
Peas, Dried		35-40	50-60	....	0.28	0.22	14	....	....
Peppers		32	40-45	85-90	0.90	....	....	30.1	2.35
Pineapples, Ripe		40-45	50	85-90	0.90	....	127	29.9	....
Plums		31-32	40-45	80-85	0.83	....	115	28.0	....
Pork, Fresh		30	36-40	85	0.60	0.38	66	28.0	....
Potatoes, White	—30	36-50	45-60	85-90	0.77	0.44	105	28.9	0.85
Poultry, Dressed	—10	28-30	29-32	....	0.80	0.41	99	27	....
Pumpkins		50-55	55-60	70-75	0.90	....	....	30.2	....
Quinces		31-32	40-45	80-85	0.90	....	....	28.1	....
Raspberries		31-32	40-45	80-85	0.89	0.46	125	30.0	[illegible].3
Sardines, Canned		....	35-40	....	0.76	0.410	101	....	....
Sausage, Fresh		31-36	36-40	80	0.89	....	....	....	....
Sauerkraut		33-36	36-38	85	0.91	0.47	128	....	....
Squash		50-55	55-60	70-75	0.90	....	....	29.3	....
Spinach		32	45-50	85	0.92	....	....	30.8	....
Strawberries	—15	31-32	42-45	80-85	0.92	0.48	129	30.0	3.3
Tomatoes, ripe		40-50	55-70	85-90	0.95	.. ...	135	30.4	0.5
Turnips		32	40-45	95-98	0.90	....	....	30.5	1.0
Veal	—15	28-30	36-40	....	0.71	0.39	91	29	....

21-15. Temperature, specific heat, and latent heat data for the more common foods. (Bush Mfg. Co.)

no contrary influences to impede the air flow. Any horizontal baffle or coil deck must be insulated because the top surface is in contact with very cold air while the under part of the baffle is in contact with relatively warm air. If it were not insulated, this temperature difference would not be maintained and

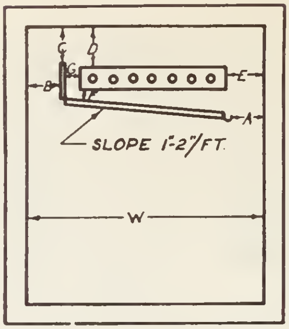
eddy currents of air would result (small circular flows of air) disturbing the air flow in the cabinet. Baffled coils are always of the natural convection type, and the air flow around the box is due only to the relative weights of the cold air and the warm air (density). The warm air is lighter per cubic foot of volume and, therefore, rises in the box. This natural circulation must never be hindered or the box temperature will not be constant. Baffling the coils tends to promote this natural circulation of the air and to speed it up.



21-16. The circulation of air in an overhead coil refrigerator cabinet.

21-10. COIL BAFFLES FOR WALK-IN COOLER

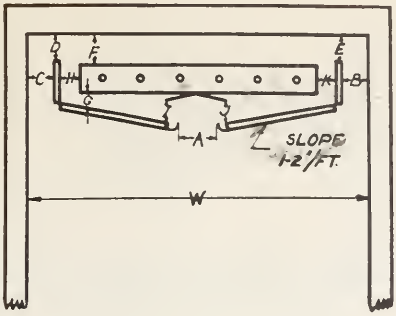
A typical baffle problem is an overhead coil installation in a walk-in cooler. This method is used in a cabinet where sufficient head room remains after the baffle has been installed. The coil is centrally located in the top of the box and the baffle surrounds it in a certain mathematically proportioned manner. The baffles are divided into two styles called the single baffle and the double baffle. The chutes or flues through which the air is made to flow are proportioned to the size of the box. The easiest way to do this is to consider the sizes of these flues in relation to the floor area of the cabinet. The cold flue or chute must



21-17. A single baffle arrangement. A. Cold air flue = $\frac{W}{7}$; B. Warm air flue = $\frac{W}{6}$; C. Same as B; D. C + 1 in.; E. A. + to 4 in.; F. 3 to 4 in.; G. 4 to 7 in.

have an area of approximately one-sixth or one-seventh the area of the floor of the box and the warm air flue must be slightly larger than this to provide for the expansion of the air as it warms up. It is understood that the baffle runs the full length of the cabinet and it always directs the air around the shortest route (the width of the box), Fig. 21-17. The warm air flue is frequently made the same size as the cold air flue although a width of one-sixth the width of the cabinet should be used. This figure means a slight increase in size of the warm air flue over that of the cold air flue. As the warm air rises in the warm air flue, it must flow over the vertical baffle to reach the coils. The area of the opening at the top of this baffle must therefore be equal to that of the warm air flue.

These overhead coils are used in cabinets which have an exterior height of 9 ft. 10 in. The exact construction of the baffle depends upon the width of the cabinet. If the width is less than 7 ft. internal dimension, a single baffle may be used, but if the width exceeds this value a double baffle must be used. This double baffle is a construction wherein the cold air is admitted to the center of the box and the warm air rises along



21-18. A double baffle arrangement. A. Cold air flue = $\frac{W}{7}$; B. Same as C. warm air flues, each are $\frac{W}{12}$; D = E = B; F. E. + 1 in.; G. 3 to 4 in.; H. Same as K, i.e., 4 to 7 in.; I. Same as J, i.e., $\frac{W}{14}$.

the two sides. Fig. 21-18. The same basic rules hold as well for the double flue as for the single flue types. The total width of the cold air flue must be 1/7 W. and the total of the warm air flues may be 1/6 W. or 1/7 W. This means that each warm air flue is 1/12 W. or1/14 W. to permit the air that goes up the warm air chute to pass over into the coil chamber. The opening between the vertical baffle and the ceiling of the cabinet must be the same size as the warm air flue, namely 1/12 W. or 1/14 W. The slope of the horizontal baffle should be between 1 and 2 in. per foot of length.

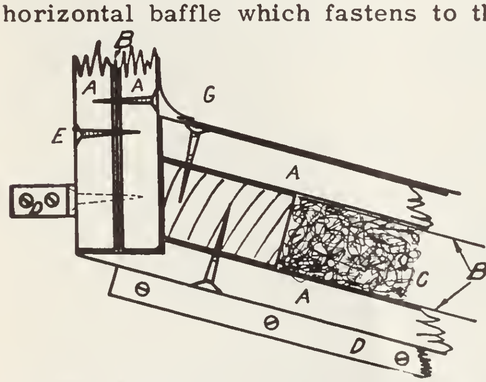
The other dimensions in baffle construction vary somewhat as to the policy followed. It is best to give the baffle as much depth as one conveniently can within the cabinet, but it is recommended that this over-all dimension be not more than $2\frac{1}{2}$ ft. The exact construction of the baffle depends on the type of coil to be mounted within it. If it is a shallow coil of from 6 in. to 8 in. in depth, this coil should have the top of it 1 in. below the top edge of the vertical baffle; this value should be increased as much as possible, still allowing the head room necessary in the cabinet. In other words, a distance of two or more inches from the top edge of the coil to the top of the vertical baffle is preferable. If a deep coil is used, i.e., 16 in. to 20 in. deep, it is sometimes necessary to permit the top of the coil to be above the top edge of the vertical baffle. This tends to decrease the efficiency of the baffle construction as it cools the air before it is below the vertical baffle edge, giving it a tendency to flow back through the warm air flue. Under this condition, the coil must be at least two inches from the ceiling of the cabinet. The space between the vertical baffle and the coil proper should not be less than 4 in. or more than 7 in. If less, the effective area of the coil is decreased. If it is more, air turbulence results, and some of the air is not cooled sufficiently as it goes through the baffle. The coil should be kept 3 in. or more above the horizontal baffle and it should never be allowed to overhang the flues. That is, in a single baffle construction, the coils should not be allowed to extend over the cold air flue, because this would permit moisture to drip on the contents below. The baffle must be provided with an adequate drain to take care of all condensation from the coil, and it is best made from galvanized iron built to provide its own drainage slant.

21-11. MULTIPLE BAFFLES

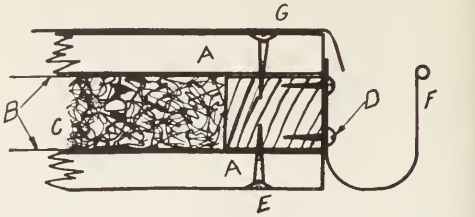
Overhead cooling coils may be obtained with multiple baffles. These baffles are narrow strips of metal (aluminum) or are of a plastic material. They each have their own drain and the condensate then drains to a manifold drain. Sweating on the under side of each baffle is prevented by maintaining multiple down drafts of air to prevent eddy air currents of warm air from contacting the underside of the baffle strips.

21-12. BAFFLE CONSTRUCTION

The vertical baffle is usually made of two thicknesses of $\frac{1}{2}$-in. spruce lumber constructed with building paper between the two boards giving a total thickness to the vertical baffle of approximately 1 in. The horizontal baffle must be insulated inasmuch as the top surface of it comes in contact with extremely cold air, whereas the bottom of the baffle comes in contact with relatively warm air. This baffle is also constructed of two layers of spruce wood $\frac{1}{2}$ in. thick, but in addition 1 in. of insulation is mounted between these two surfaces. During the construction of the baffle, the insulation should be sealed with hydrolene, Fig. 21-19. The top surface of the baffle should be covered with galvanized iron, which must be constructed so the metal will extend partially up to the vertical baffle and also over into the drain trough at the other end of the baffle, Fig. 21-20. Cadmium-plated brass or other rust-proof nails must be used throughout. The vertical baffle is usually fastened permanently into the cabinet by means of angle irons or wood cleats. The horizontal baffle may be fastened at its two ends by the same method. That part of the horizontal baffle which fastens to the vertical baffle is hinged to it, and the other end is held up by hooks and eyes.

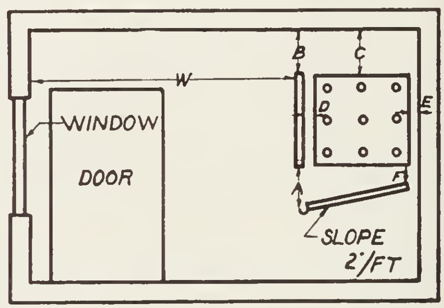


21-19. Baffle details (deck and baffle). A. $\frac{1}{2}$-in. spruce; B. Sealing paper; C. Insulation; D. Cleats; E. Wood screws; G. Galvanized iron.



21-20. Baffle trough detail. A. $\frac{1}{2}$-in. spruce; B. Sealing paper; C. Insulation; D. Cadmium plated wood screws; E. Brass wood screws; F. Galvanized iron trough; G. Galvanized iron deck covering.

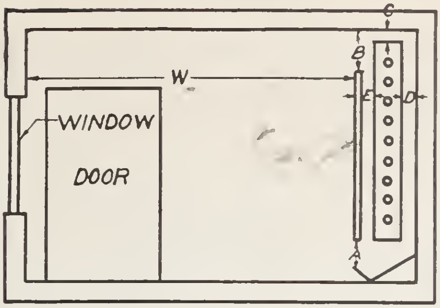
This construction permits very easy periodical cleaning of the baffle, and also makes the coil more accessible to the service man. The more modern cabinets, especially those constructed for mechanical refrigeration, have the baffles already constructed within.



21-21. Corner coil and baffling in a walk-in cooler. W. Width from wall to baffle; A. $\frac{W}{7}$; B. $\frac{W}{7}$; C. B + 1; D. 2 in.; E. 2 in.; F. 2 in.

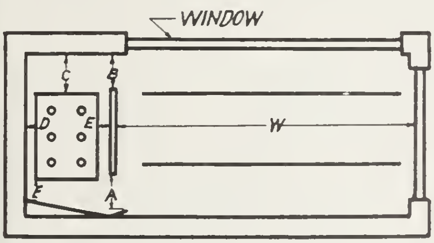
21-13. BAFFLES FOR ODD SIZE COILS

Many cabinets do not have room to mount overhead coils such as one type of walk-in cooler which is constructed with an exterior height of approximately $7\frac{1}{2}$ feet. This height necessitates some other coil mounting, and two types of mountings are sometimes used. (1) In one method the coil is put in the upper corner of the cabinet as far as possible from the entrance door to the cabinet, Fig. 21-21. (2) The other



21-22. Wall coil and baffling in a walk-in cooler. W. Width from wall to baffle; A. $\frac{W}{7}$; B. $\frac{W}{7}$; C. 2 in.; D. 2 in. E. 2 in.

method uses a wall coil mounted against the wall opposite the windows or the reach-in doors of the cabinet, Fig. 21-22. These coils are baffled, using the same basic values for air flues as the overhead coil. Note that the horizontal baffle in Fig. 21-21 is built to allow a 1-in. space between it and the wall in



21-23. End bunker baffle arrangement. W. Length from end of counter to baffle; A. $\frac{W}{7}$; B. $\frac{W}{7}$; C. B + 1 in.; D. 2 in.; E. 2 in.; F. 3 in.

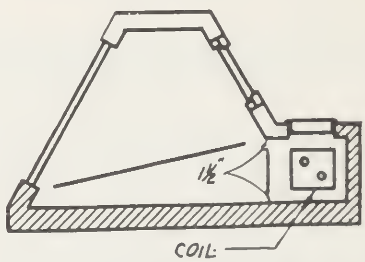
order to permit a small circulation of air underneath the baffles, thus keeping correct refrigeration in this space. In this construction the vertical baffle is the one insulated. The construction of the baffles is identical to the construction described in Paragraph 21-12.

21-14. DISPLAY COUNTER BUNKERS

Overhead coil and end bunker display cabinets are baffled for the same reason as in the overhead coil, walk-in cooler. However, the end bunker basic distance (W) is the distance from the baffle of the coil or coils to the extremity of the counter. Fig. 21-23. In the display counter the basic distance (W) is the intermediate width of the cross section. That is, if the top of the display case is only 1 foot wide and the bottom is 3 feet wide, the basic distance (W) is 2 feet. As in the case of the walk-in cooler, these cabinets frequently come with the baffles already constructed within, Fig. 21-24. In this case standard baffle designs are installed, as have been found to be best in actual tests.

21-15. GROCERY CABINET BAFFLES

Grocery cabinet coils are located in the upper center of the cabinet and are baffled with the typical double baffle system. The basic width or W upon which to calculate the various dimensions is the total of the two distances from the vertical baffles to the end walls. That is, if the interior width of a

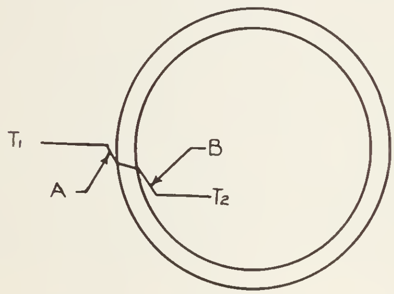


21-24. Display case rear bunker baffle arrangement.

grocery cabinet is 5 ft. and the coil space plus the baffle thickness takes up $2\frac{1}{2}$ ft, the baffle dimensions or flues will depend upon the $2\frac{1}{2}$ ft. remaining distance or space. The coils cannot be placed as far from both the ceiling and the baffles as in the walk-in coolers; therefore 2 in. is specified as the minimum distance for these spaces.

21-16. COOLING COIL TYPES

Many kinds of cooling coils have been used in mechanical refrigeration, but there have been in use two basic types. One type of coil is used to cool the air within the cabinet directly, while the other type of coil is used to cool a liquid which may be either consumed or used to cool other substances. These are called (1) air-cooling coils, (2) liquid-cooling coils. The air-cooling coils may be further classified as the dry and the flooded type, both of which may be either of the frosting, the defrosting, or the non-frosting type. Also there are forced circulation coils of either the flooded or dry type. The liquid cooling coils may be subdivided into the submerged coil and the tube-within-a-tube coil. In commercial refrigeration certain kinds of coils are tending to become more popular than others. Among these are the dry non-frosting air cooling coils, the forced circulation dry coils, and the submerged flooded or dry coil. See Chapter 19.



21-25. Heat transfer from air surrounding a coil, to the coil, through the coil and to the refrigerant inside.

21-17. AIR COOLING COIL THEORY

The theory involved in the transfer of heat from the air circulating over the coil to the refrigerant is that, as the warm air comes in contact with the coil, the air molecules striking the fins release some of their energy to the fin (transfer the heat to it). This heat in turn travels through the fins, then through the tubing of the coil, and coming in contact with the liquid refrigerant on the inside, tends to boil it. The greatest heat transfer problem in this case is that of moving the heat in the air to the fin due to the low density of air. After reaching the metal, the heat travels very efficiently and rapidly, but upon reaching the interior surface of the tubing, it again incurs difficulty in reaching the refrigerant in the system due to such things as gas bubbles clinging to the internal surface and an oil film on it.

21-18. COOLING COIL CAPACITIES

One of the laws of thermodynamics (heat in action) is that heat always flows from a higher temperature to a lower temperature. As in the case of the heat leakage, the amount of the heat leakage depends on four variables (1) area, (2) temperature difference, (3) thickness of the material and (4) time. The kind of material used in cooling coils is of utmost importance since the materials used must be very good heat conductors.

The heat transmission is through various materials. For air cooling coils, the heat must pass through an air film on the metal surface, through the metal and then through an oil or liquid refrigerant film on the inside of the coil, Fig. 21-25.

If the air is moved rapidly, the heat flow is greater because, first more air contacts the metal per unit of time and second the air film is thinner and therefore the heat conductivity is greater.

If the oil or refrigerant film is moved faster or if it is thinner due to greater movement, this also will in-

crease the rate of heat flow.

Generally speaking, the denser the fluid the greater the heat flow, and the faster the fluid motion, the greater the heat flow.

The U factor for natural convection coils is approximately

1 Btu/sq. ft./F/ hr.

The U factor for blower coils is approximately

3 Btu/sq. ft./F/ hr.

The U factor for liquid cooling coils is approximately

15 Btu/sq. ft./F/ hr.

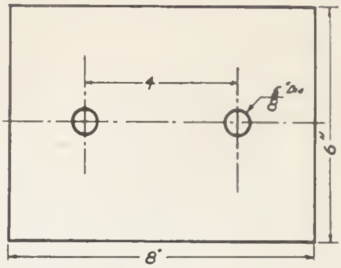
21-19. COOLING COIL AREA

It is best when calculating or determining the capacity of these coils to rely on the manufacturer's specifications inasmuch as they obtain their heat capacity values from actual experimental investigation. Such things as poor circulation, frosted fin condition, air turbulence around the coil, and even the amount of moisture in the air will affect the capacity of the coil tremendously. To calculate the external surface area of a coil, care must be taken to consider such things as both surfaces of the fin, the outside surface of the tubing (neglect the area where it comes in contact with the fins) and the external surface of the float chamber. For example, to find the area of a coil (Fig. 21-26) with 6-in. x 8-in. fins .025-in. thick 10 ft. long, having $\frac{1}{2}$-in. fin spacings and using two 5/8-in. tubes 4 in. apart is as follows:

I. The total number of fins
   $10 \times 12 \times 2 = 240 + 1$ (extra end fin) $= 241$ fins
   Fin area = area of each side of the fin minus the area replaced by the tubing.

II. Area of one fin $= 8'' \times 6'' \times 2 - \frac{\pi(5/8)^2}{4}\ 2 \times 2 =$
   The $8'' \times 6'' \times 2$ = the gross area of both sides of the fin

The $\frac{\pi(5/8)^2}{4} \times 2 \times 2$ = area of hole



21-26. Cooling coil fin specifications for sample problem.

x 2 holes x 2 sides to the metal removed.

The $\frac{\pi(5/8)^2}{4}$ is obtained from the formula

Area of a circle $= \pi r^2$ (r = radius and $\pi = 3.1416$)

$2r$ = diameter =

$\pi\frac{(d)^2}{2} = \pi\frac{d^2}{4} = \pi\frac{d^2}{4}$

$96 - \frac{80}{64} = 94.75$ sq. in. per fin

III. Total fin area $= 94.75 \times 241 =$ 22,835 sq. in.

IV. Area of 2 tubes 5/8-in. D; 10 feet long $2 \times \pi 5/8 \times 120 = 15.71 \times 30 =$ 471.3 sq. in.

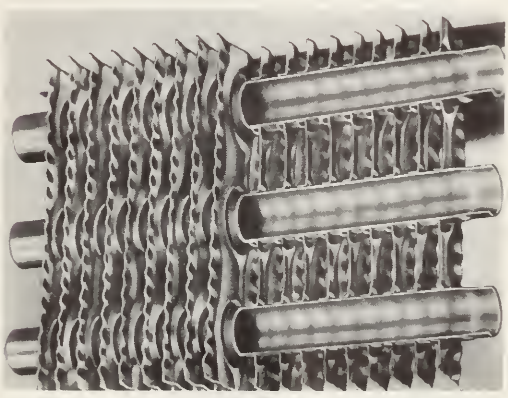
V. The actual tube area is decreased by the thickness of the fins, i.e., the following amount:
   Fin contact area $= \pi 5/8 \times .025 \times 241 = 15.71 \times .025 \times 241 = 12.17$ sq. in.
   Actual tube area $471.3 - 12.17 =$ 459.13 sq. in.

VI. Tube bend area = length of bend x circumference length = 2'' radius x π
   circumference = 5/8'' x π
   Area = $2'' \times \pi 5/8 \times \pi = 10/8 \times 9.87$ = 12.2 sq. in.

VII. Total area 22,835
459.13
12.2
23,306.33 sq. in.
or in sq. ft. 23,306.33 ÷ 144 =
161.85 sq. ft.

The coil is unable to remove heat from the cabinet when the compressor is not running. Therefore, the heat removing capacity of a coil is calculated on the same running time as that of the compressor. The allowable calculated time for the condensing unit to run and, therefore, the allowable time for the coil to remove heat from the box during a 24-hour period, varies between 14 and 18 hours in commercial applications.

An example of heat transfer ability is as follows: What is the capacity of a coil having an external area of 15 square feet with a refrigerant temperature of 22 F., if the average box temperature is 42 F.?



21-27. A section through the tubes and fins of a popular cooling unit.
(McQuay Inc.)

Solution: First, it is known that 1 square foot will handle 1 Btu per F. per hour. This means that 1 square foot will handle 6 Btu's per day based on 16 hours running time. The refrigerant temperature is 22 F.; with the air temperature passing over the coil at 42 F., the temperature difference is 20 F. If 1 F. temperature difference will handle 16 Btu., 20 F. will handle 320 Btu (20x16), then multiply this value by the number of sqaure feet, and we have the total capacity of the coil per area x time x temperature difference. In this case Btu = 1 x 16 x 1 x 20 = 4,800 Btu per 24 hours.

It is claimed that the maximum effective distance that the fin should extend from the coil should not exceed 3 inches. See Fig. 21-27.

21-20. FROSTING COILS

A frosting coil is a coil which frosts continuously when in use, operating at temperatures always below 32 F.; the machine must be manually or automatically shut down periodically to rid the system of frost. These coils run at extremely low temperatures to keep the fixture cool, which results in an accumulation of frost and ice on them; as this accumulation of frost grows thicker, it decreases the cooling efficiency of the coil tremendously. These coils are used in frozen food fixtures of all types.

21-21. DEFROSTING COILS

Many coils run on what is called a defrosting cycle, that is, when the condensing unit is running, the temperature of the cooling coil is such that frost accumulates on it, but after the compressor shuts off, the coil must warm up above 32 F. before the condensing unit will start again. The frost accumulation then melts off. This keeps the fin surfaces clear and promotes a more consistent and efficient heat transfer ability of the coil. This is done, however, at a sacrifice to temperature differences between the coil and the air in the cabinet and a greater coil area is needed to compensate for this. The basic calculations are the

COILS AND COIL & PAN COMBINATIONS FOR 8 FT. WALK-IN COOLERS

				Coil and Pan Combinations				Coils Only			
BOX SIZE	BTU-HR 15°TD	SQ FT SURF.	NO. COILS	MODEL NO.	Dimensions in Inches D	W	L	MODEL NO.	Dimensions in Inches D	W	L
5 x 4	2496	161	1	548P	13	24	46	C548	7	21	40
5 x 5	3094	199	1	558P	13	27	48	C558	7	24	42
6 x 4	3120	201	1	648P	13	24	54	C648	7	21	48
6 x 5	3225	206	1	658P	10½	38	57	C658	3	35	50
6 x 6	4160	234	1	668P	13	32	54	C668	7	28	48
7 x 4	2808	178	1	748P	10½	32	68	C748	3	28	62
7 x 5	3600	229	1	758P	10½	38	62	C758	3	35	55
7 x 6	3975	253	1	768P	10½	38	67	C768	3	35	60
7 x 7	4568	276	2	778P*	10½	24	70	C778*	3	21	64
8 x 5	3848	249	1	858P	10½	38	73	C858	3	35	66
8 x 6	4425	283	1	868P	10½	38	73	C868	3	35	66
8 x 7	4815	292	1	878P	10½	38	75	C878	3	35	68
8 x 8	5513	342	2	888P*	10½	24	75	C888*	3	21	68
9 x 6	4725	295	1	968P	10½	38	87	C968	3	35	80
9 x 7	5205	329	1	978P	10½	38	83	C978	3	35	76
9 x 8	5928	372	2	988P*	10½	24	90	C988*	3	21	84
10 x 6	5250	327	1	1068P	10½	38	95	C1068	3	35	88
10 x 7	5700	350	1	1078P	10½	38	101	C1078	3	35	94
10 x 8	6075	385	2	1088P*	10½	24	95	C1088*	3	21	88
10 x 10	7500	465	2	1008P*	10½	24	97	C1008*	3	21	90
11 x 6	6500	406	1	1168P	10½	38	114	C1168	3	35	108
11 x 7	6240	392	2	1178P*	10½	24	95	C1178*	3	21	88
11 x 8	7020	429	2	1188P*	10½	24	105	C1188*	3	21	98
12 x 6	6368	387	1	1268P	10½	38	112	C1268	3	35	105
12 x 7	7020	429	2	1278P*	10½	24	105	C1278*	3	21	98
12 x 8	7410	458	2	1288P*	10½	24	109	C1288*	3	21	102
12 x 10	8400	516	2	1208P*	10½	24	122	C1208*	3	21	115
12 x 12	9113	534	2	1228P*	10½	32	119	C1228*	3	28	112
14 x 8	8580	521	2	1488P*	10½	24	136	C1488*	3	28	128
14 x 10	9750	606	2	1408P*	10½	24	140	C1408*	3	21	133
14 x 12	10500	614	2	1428P*	10½	32	135	C1428*	3	28	128
14 x 14	12075	710	2	1448P*	10½	38	126	C1448*	3	35	119
16 x 8	9240	535	2	1688P*	10½	24	154	C1688*	3	21	148
16 x 10	10692	618	2	1608P*	10½	24	176	C1608*	3	21	170
16 x 12	12636	783	2	1628P*	10½	24	176	C1628*	3	21	170
16 x 14	14256	825	2	1648P*	10½	24	176	C1648*	3	28	170

Note: All dimensions above are for one coil and one pan in combination or one coil only.

Asterisk (*) appearing after model number denotes that 2 coils and 2 pans or 2 coils without pans are supplied by specifying designated model number.

COILS AND COIL & PAN COMBINATIONS FOR 10 FT. WALK-IN COOLERS

				Coil and Pan Combinations				Coils Only			
BOX SIZE	BTU/HR 15°TD	SQ FT. SURF	NO. COILS	MODEL NO.	Dimensions in Inches D	W	L	MODEL NO.	Dimensions in Inches D	W	L
5 x 4	2925	192	1	541P	13	35	40	C541	7	31½	33
5 x 5	3861	249	1	551P	13	35	47	C551	7	31½	41
6 x 4	3432	220	1	641P	13	24	58	C641	7	21	52
6 x 5	3780	242	1	651P	13	24	57	C651	7	21	50
6 x 6	4570	292	1	661P	13	32	58	C661	7	28	52
7 x 4	3900	248	1	741P	13	24	64	C741	7	21	58
7 x 5	4140	269	1	751P	13	24	62	C751	7	21	55
7 x 6	4410	286	1	761P	13	24	65	C761	7	21	58
7 x 7	5824	369	1	771P	13	32	70	C771	7	28	64
8 x 5	4613	286	1	851P	13	24	73	C851	7	21	64
8 x 6	5025	310	1	861P	13	24	78	C861	7	21	71
8 x 7	5325	348	1	871P	13	24	75	C871	7	21	68
8 x 8	5850	359	2	881P*	10½	24	78	C881*	3½	21	71
9 x 6	5513	386	1	961P	10½	38	87	C961	3½	35	80
9 x 7	6000	390	1	971P	13	27	83	C971	7	24½	76
9 x 8	6512	383	2	981P*	10½	32	88	C981*	3½	28	82
0 x 6	6113	386	1	1061P	10½	38	95	C1061	3½	35	88
10 x 7	6593	412	1	1071P	10½	38	101	C1071	3½	35	94
10 x 8	7275	453	2	1081P*	10½	24	95	C1081*	3½	21	88
10 x 10	8400	622	2	1011P*	10½	32	95	C1011*	3½	28	88
11 x 6	6370	391	1	1161P	10½	38	112	C1161	3½	35	106
11 x 7	7254	453	1	1171P	10½	46	107	C1171	3½	42	101
11 x 8	7800	486	2	1181P*	10½	24	114	C1181*	3½	21	108
12 x 6	6900	426	1	1261P	10½	38	120	C1261	3½	35	113
12 x 7	7392	429	1	1271P	10½	46	126	C1271	3½	42	120
12 x 8	7650	472	2	1281P*	10½	24	112	C1281*	3½	21	105
12 x 10	9375	546	2	1211P*	10½	32	122	C1211*	3½	28	115
12 x 12	10500	616	2	1221P*	10½	38	111	C1221*	3½	35	104
14 x 8	9672	601	2	1481P*	10½	24	138	C1481*	3½	21	132
14 x 10	10648	619	2	1411P*	10½	32	135	C1411*	3½	28	129
14 x 12	12480	777	2	1421P*	10½	32	134	C1421*	3½	28	128
14 x 14	13125	766	2	1441P*	10½	38	135	C1441*	3½	35	128
16 x 8	11544	716	2	1681P*	10½	24	162	C1681*	3½	21	154
16 x 10	11880	689	2	1611P*	10½	32	149	C1611*	3½	28	143

These recommendations are for refrigerators constructed with 4" cork or equivalent, and are based on 55 degrees temperature difference (box to room temperature) with normal service.

21-28. A table of capacities for a popular non-frost coil. (Tenney Engineering, Inc.)

same, the only change being a smaller temperature difference.

21-22. NON-FROSTING COILS

The non-frosting coils serve the same heat transfer purpose as the ones already mentioned with the exception that they operate at a temperature which is never below 31 F. This temperature permits only a very slight formation of frost which disappears immediately when the condensing unit stops.

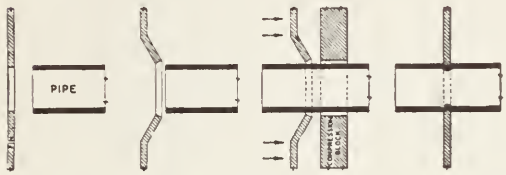
A non-frosting coil operating with natural convection (gravity) and placed to extensive cooling surfaces at the top of a box is often referred to as a "flash" coil. These coils are shallow in depth and are usually provided with pans to collect drain condensation.

A typical coil capacity table as listed in a catalog of non-frosting coils is shown in Fig. 21-28.

21-23. COOLING COIL DESIGN

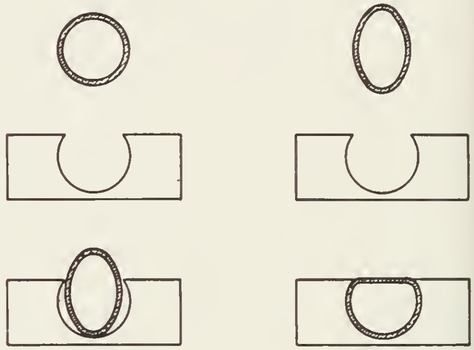
Many types of dry coils are being made at present using the following combinations: copper tubing and aluminum fins, copper tubing and copper fins and aluminum tubing (for

ammonia). The fins are usually securely bonded to the tubing; however, some manufacturers construct the fin to fit the tubing with a drive fit. Some manufacturers dip the whole coil in a tinning bath after assembling; others use some mechanical device to attach the fins firmly to the tubing. Some



21-29. An illustration showing mechanical means of bonding cooling fins to tubing.
(Peerless of America)

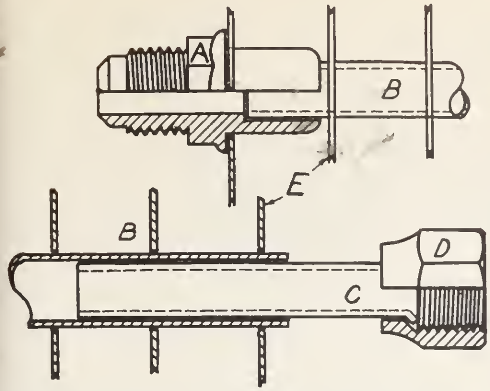
expand the tubing with a mandrel or by hydraulic pressure to expand it against the fin. See Fig. 21-29. A method of bonding tubing to off-center fins is shown in Fig. 21-30. The fin spacings vary between 1/2 and 1 1/2 inches. This spacing is a means of varying the capacity of the coil and is also used to compensate for the depth of the coil. The deeper the coil, the greater the fin spacing to minimize air restriction. Coils which have a 6 in. to 8 in. depth may be usually found to have 1/2 in. spacings and 10 in. and 12 in. depth coils will have 1 in. spacings, whereas the 18 in. or 20 in. coils will have the 1 1/2 in. spacings. Fin spacings of 1 in. or less are said to decrease air turbulence. The tubing used in the coil is usually 5/8 in. O.D., although 3/4 in. O.D. tubing is used in the large coils. Some companies use one continuous piece of tubing for the complete coil; others have all bends made separately. The bends are silver brazed or brazed to the straight lengths. Some companies use internal devices inside the tubing to swirl the refrigerant to improve heat transfer to the boiling refrigerant. The refrigerant fittings to the coil are usually 1/2 in. O.D. tubing soldered to the 5/8 in. tubing and then flared with an external nut mounted on it. Some manufacturers use a 1/2 in. male flare fitting, brazed to the end fin, Fig. 21-31. The corners of the fins should be braced or reinforced using some method to eliminate bending while the coil is being installed. This often consists of right angle strips either clamped or soldered to the fins. Some concerns fit a strip of metal into a slot cut in the corner of each fin. One company uses fins of stamped fluted construction which enables them to use a coil of the same area as other coils in a smaller overall space.



21-30. A method of mechanically bonding tubing to off-center fins.
(Peerless of America)

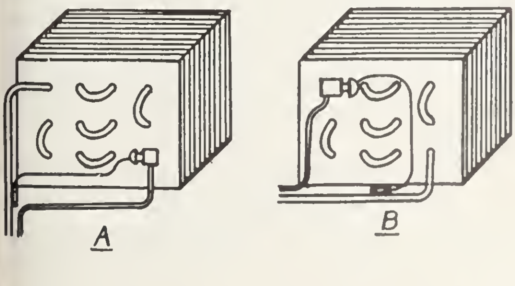
21-24. COIL MOUNTING

The coils are mounted in the cabinet either by suspending them from the ceiling, by mounting them on pipe, which is fastened to the vertical baffle and the wall of the cabinet, or by mounting them on stands fastened to the horizontal baffle. The thermostatic expansion valve may be mounted to the top of the coil, allowing the refrigerant and oil to flow by gravity to the suction line down to the compressor, or the expansion valve may be connected to the bottom of the coil making the refrigerant pass upward to come to the suction



21-31. An illustration of construction of coupling devices used in attaching refrigeration lines to cooling coils.

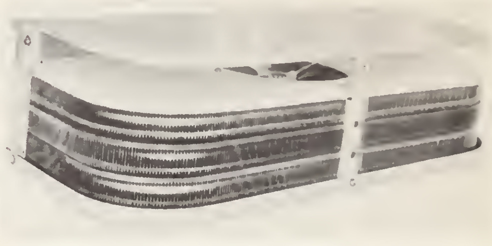
line. The argument for each of these installations is that if the expansion valve is fastened to the upper part of the coil permitting a gravity flow, oil binding will be negligible, but the fins will be coldest at the top in contact with the warm air. If the expansion valve is fastened to the bottom of the coil, the warmer tubing comes in contact with the warmer air first. This theory is in line with water-cooled condenser efficiencies, but the oil return difficulty results in slugging and surging of the refrigerant. Having the refrigerant pass upward as it goes through the coil tends to eliminate frosting down the suction line in most cases. Both methods of installation have their advantages, Fig. 21-32.



21-32. An illustration showing the two methods of mounting a thermostatic expansion valve on cooling coils. A. Bottom mounted; B. Top mounted.

21-25. FORCED CIRCULATION AIR-COOLING COILS

A forced circulation coil is one having an electric fan mounted in conjunction with it in order to produce a flow of air past the coil. Velocities of 44 feet per minute to 2,000 feet per



21-33. A forced convection air cooling coil. (Bush Mfg. Co.)

minute are permissible with 1,000 feet per minute being the average value. The coils are finned and the spacing of the fins varies between 3/16 in. and 5/16 in. Draining facilities for condensation removal must be built into the unit, Fig. 21-33. Sometimes motors are provided with variable speeds, but it is more economical to have a one-speed fan. Because of the large amount of air striking the coil per unit of time, the capacity of the coil in Btu per square foot per F. hour is increased remarkably. The values naturally vary with the air speed and the table, Fig. 21-34, gives an approximation of these changes. So many variables enter a calculation of this nature that no special values can be given in this text; the manufacturer's recommendations should be followed. The table, however, will give one a general idea as to the capacity of these coils. For example, one coil has a capacity of 4.6 Btu/sq. ft./F./ hr. at 240 cu. ft./min. Because the forced air puts more heat into the coil surface, the fin area is less and also the fins do not extend as far from the primary surface.

Surface in Sq Ft.			Parallel Paths	Cooling Capacities B.T.U. per Hour		Motor		Fan	
Tube	Fin	Total		15° F. T.D.	25° F. T.D.	H.P.	Speed R.P.M.	Diameter	C.F.M.
2.94	32.39	35	3	2200	4500	1/80	1800	12"	620
5.88	63.0	68	5	4100	7200	1/80	1800	12"	465
7.94	70.06	78	3	5200	9000	1/10	1140	15½"	1200
13.2	116.8	130	5	8300	12300	1/10	1140	15½"	1000
14.7	83.3	98	3	6500	10500	⅛	1140	17"	2020
17.2	145.8	163	5	10000	14000	⅛	1140	17"	1715

21-34. A table of forced circulation cooling coil ca pacities. (McCord Radiator & Mfg. Co.)

21-26. LIQUID COOLING COIL CAPACITIES

Liquid cooling coils, regardless of their type may be calculated for capacity on the basis of a factor of approximately 10 to 120 Btu per square foot per F. per hour. However, the U factor varies with the fluid velocity, coil construction and the total temperature difference. Fig. 21-35 shows the average values for a certain coil. Some of these coils are used to cool a brine

Water Velocity	Total Temperature Difference				
	6	8	10	12	15
150	67	76	83	90	97
200	83	95	103	110	118
250	97	109	115	122	129
300	103	115	123	130	138

21-35. The heat transfer for a typical flooded liquid cooler using ⅝" o.d. tubes. (Btu sq. ft. hr F).

solution which, inasmuch as it is a non-freeze solution, does not have any frost accumulation problems. Many submerged coils use a sweet water bath to provide an ice holdover around the coils and thus maintain a good capacity during peak loads. The capacity of these coils varies tremendously depending upon whether or not they are of the frosting type. As one can understand from the theory of heat transfer, when ice forms around the coil, it necessitates that the heat go through this extra material in order to be removed from the liquid. Cooling capacity of the coil is decreased. Furthermore, it makes the heat travel through one extra contact surface which reduces efficiency. Liquid cooling coils are used for beverage cooling and for cooling brines for air conditioning.

21-27. SPECIAL COIL CAPACITIES

A considerable variation of cooling coil types may still be found in use including: cast metal coils, iron pipe coils, brine spray coils, and intermediate refrigerant coils. The problems incurred with these will be the same as the ones discussed previously. The metal used as the refrigerant carrying device does not have much effect upon the heat transfer capacity of the coil, because its conductivity is relatively so much greater than that contact between the coil and the air that it may be neglected. The capacity of the cast metal coil and the iron pipe coil may be calculated exactly the same as the method described in Paragraph 21-19.

Some installations use brine spray. In this system the brine is forced through a pipe extending into the cooling chamber, and this pipe is perforated with a number of fine holes. The brine sprays out of these holes and mixes with the air flowing over the baffle

Usage	Final Temp. Required °F.	Total Amount of Water Used and Wasted
1. Office Building—Employees	50	1/8 gallon per hour per person
2. Office Building—Transients	50	1/2 gallon per hour for each 250 persons per day
3. Light Manufacturing	50 to 55	1/5 gallon per hour per person
4. Heavy Manufacturing	50 to 55	1/4 gallon per hour per person
5. Restaurant	45 to 50	1/10 gallon per hour per person
6. Cafeteria	45 to 50	1/12 gallon per hour per person
7. Hotels	50	1/2 gallon per day per room (14 hr. day)
8. Theaters	50	1 gallon per hour per 75 seats
9. Stores	50	1 gallon per hour per 100 customers per hour
10. Schools	50 to 55	1/8 gallon per hour per student
11. Hospitals	45 to 50	1/12 gallon per day per bed

Note—Total amount of water used and wasted varies with type of installation and kind of service This table will serve as a basis for determining cooler capacity required

21-36. A drinking water cooling table giving the values of various applications.
(Temprite Products Corp.)

removing the heat. The capacity of these systems is calculated upon the temperature difference between the air in the box and the temperature of the brine. It is safe to assume a high efficiency of heat transfer for brine spray installations.

The Baudelot Cooler (milk cooler) runs water or the liquid to be cooled over refrigerant cooled pipes or plates. The liquid being cooled is in the open and can be easily controlled. Icing is not critical and therefore the liquid can be cooled very close to its freezing temperature.

21-28. WATER COOLING LOADS

The problem of determining the refrigeration load of a water-cooled installation is basically a specific heat and heat leakage problem combination. The water is cooled to temperatures which vary upward from 35 F., and the amount of heat removed from the water to cool it to a predetermined temperature is a simple specific heat problem. The water, being maintained at these low temperatures, results in a heat leakage from the room into the water, and this part involves the heat leakage portion of the installation. The two major factors to be solved in a water-cooling installation are determination of how much water is to be consumed at the temperature difference desired. Fig. 21-36 is a table giving the values of these two variables as recommended by the Temprite Corp. The temperature of the water should be regulated according to the type of work the consumers are performing, the heavier the work or the warmer the room temperature the warmer the water must be. The amount of water consumed varies extensively in the different applications. By using this table for obtaining the initial values, the exact heat load is easily determined after a very small amount of investigation. For example, item No. 4 in the table points out that for heavy manufacturing the water to be consumed should be kept within 50 to 55 F., and that 1/4 gallon per hour per person will be consumed. A production foundry may be classed as heavy manufacturing.

If a foundry employs 50 men for a period of 8 hours, the water load per day would be 50 x 8 x 1/4, which would represent 100 gallons quantity of water to be cooled per 8 hours. If the city water is at a temperature of 75 F. in the pipes it must be cooled 20 F. to reach the temperature of 55 F. There are 8.34 pounds of water in 1

gallon and the specific heat load would therefore be as follows:

Btu = specific heat x weight x temperature difference, therefore,

Btu = 1 x 100 x 8.34 x 20. = 16,680 Btu per 100 gal. water.

The heat leakage for this particular problem is determined by the external area of the insulated parts of the system. One to three inches of cork are common thickness for water-cooling insulations with ice water thickness insulation being standard at 1 1/2 in. The heat leakage is calculated identically with that of the heat leakage for cabinets with the exception that this insulation does not have wood on either side; the cork acts as the only insulation. The example described above deals only with a unit installation.

Many water-cooling installations involve the circulation of the refrigerated water to the various fountains. The heat leakage load in a case of this kind is calculated on the basis of gallons of water per hour to be circulated through the system to maintain satisfactory temperatures.

The table Fig. 21-37 illustrates the tabular method of computing this load.

21-29. ICE CREAM COOLING LOAD

Ice cream is manufactured from milk, solids, fat, sugar, gelatin, and water and, after mixing, the product is cooled to about 27 F. and frozen. It is then cooled rapidly to anywhere from -20 F. and is maintained between 0 to 5 F. if brick; or 5 to 12 F. if bulk; until it is dispensed. The heat values of the various ice creams vary, but the average values are: The specific heat of the mix before freezing is 0.80 and the latent heat at 27 F. is about 90 Btu per pound. The specific heat of the frozen ice cream is 0.45. The weight of the original mix is about 9 pounds per gallon; but on freezing, it expands and comes to a density of 5 pounds per gallon, if simply flavored and to 6 pounds per gallon, if it contains fruits or nuts. The heat load of cooling a mix and freezing it is easily calculated from the above.

The next problem is to determine the size of unit to maintain ice cream in its cabinets during the dispensing of the cream. Normally an ice cream cabinet is designed to hold brick ice cream and flavored ice creams next to the cooling coil; but many cabinets, especially the recent dry coil models, need separate cooling units for the two types. Vanilla ice cream may be kept at the warmest temperature, while chocolate ice cream must be kept very close to brick temperatures to keep it

Gallons per Hour To Be Circulated per 100 Feet of Pipe to Hold Temperature Rise Within 5° F. Add This Amount to Usage Fig. 21-36

PIPE SIZE	TEMPERATURE DIFFERENCE BETWEEN ROOM AND CIRCULATING WATER							
	20°	25°	30°	35°	40°	45°	50°	55°
1/4"	4.8	6.3	7.3	3.2	9.7	10.9	12.3	13.6
3/8"	5.5	6.8	8.2	9.6	11.0	12.3	13.7	15.0
1/2"	6.3	8.0	9.5	11.2	12.7	14.3	16.0	17.6
3/4"	6.7	8.4	10.1	11.8	13.5	15.2	16.9	18.6
1"	7.3	9.1	10.9	12.8	14.6	16.5	18.5	20.6
1 1/4"	8.6	10.4	12.5	14.6	16.6	18.7	20.4	22.1
1 1/2"	9.0	11.2	13.5	15.7	18.0	20.2	22.5	24.7

21-37. A table showing heat gain through insulated cold water pipes.
(Temprite Products Corp.)

from becoming soft. Old cabinets used the low side float refrigerant control and a brine tank exclusively, while at present self-contained models use either the high side float, the automatic expansion valve, or the capillary tube. Multiple systems use thermostatic expansion valves with the refrigerant tubing soldered to the ice cream com-

R.P.M.	Cooling Coil Temp.	B.T.U./hr.
	45	11000
	40	10200
475	35	9370
	30	8530
	25	7740
	25	8700
	20	7960
540	15	7200
	10	6430
	5	5740
	0	5100
	0	5780
	-5	5700
665	-10	4430
	-15	3820
	-20	3280
	-25	2800

21-38. A capacity table for a one H.P. condensing unit —air cooled—90 F. ambient temperature.

partment sleeves. Metal finished cabinets with 3 in. to 4 in. of slab cork well sealed from moisture are used.

The ice cream is delivered at the correct temperature, and the heat load is, therefore, composed only of leakage and air entering when the covers are removed. The tables (Figures 21-4 and 21-5) may be used to calculate the heat leakage for the lack of wood covering. Use the external area and add 20 per cent to take care of the cover openings.

21-30. CONDENSING UNIT CAPACITIES

After the heat load has been determined for a refrigerator, and after a cooling coil has been selected for this cabinet, a condensing unit must be chosen to balance the cooling coil capacity.

The condensing unit must match the cooling coil capacity in two ways:

(1) It must operate at the low side pressure that corresponds to the refrigerant temperature in the cooling coil.

(2) It must remove all the heat that the cooling coil removes in the same running time as was determined for the cooling coil.

When choosing the condensing unit one must find out if the condensing unit is to be water-cooled or air-cooled, whether it is to be a hermetic unit or conventional unit and what the available electric power is (such as 110 or 220 volt, single phase or 220 or 440 volt, three phase).

Fig. 21-38 is the table of data on a typical condensing unit. This is an air cooled unit with a 1 H.P. motor and it has a 2 cylinder compressor with a 2-in. bore and a 2-in. stroke.

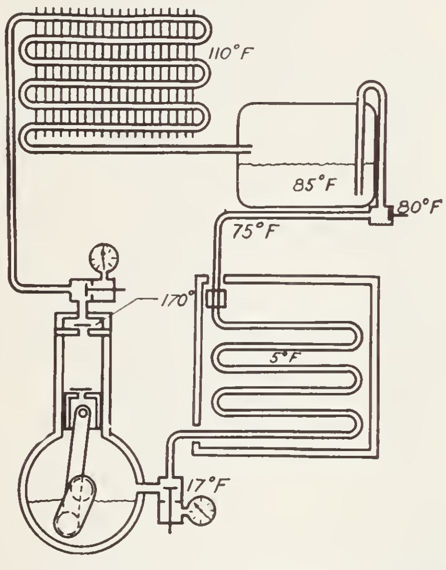
If the cooling coil was selected on the basis of a 15 F. temperature difference and a 16 hour running time, this means that if the cabinet is to operate at 38 F. the refrigerant temperature will be 38-15 or 23 F. If it is a F-12 refrigerant unit, the condensing unit capacity must be matched to a low side pressure of 23.2 psi.

21-31. REFRIGERANT PROPERTIES

To understand the operation of the condensing unit as to the compressor capacity and motor capacity, it is necessary to have a good understanding of physical properties of refrigerants and how the refrigerant does its work. The refrigerant gas is taken up by the compressor, and a pressure is imposed upon it to convert it to a high pressure, high temperature condition. This action introduces a small amount of heat energy to the refrigerant from the motor and puts it in a condition so that

it may be converted from a gas to a liquid again. It is now necessary to determine how large a compressor is needed to produce a certain amount of refrigeration, and how large a motor is needed to drive this compressor.

To understand how these values are determined it is necessary to understand the heat behavior of the refrigerant. The refrigerant cycle is simple. The refrigerant is admitted into the



21-39. A refrigerating system showing the approximate temperatures of the refrigerant in the various parts of the system.

cooling coil in the liquid state and at near room temperatures. The vaporizing of some of it under the low pressure in the coils cools the remainder of the refrigerant to the desired refrigerating temperatures, and then as the remainder of the refrigerant evaporates, it removes heat from the cabinet. The total amount of heat absorbed is the LATENT HEAT of vaporization, while the amount of heat absorbed from the cabinet and coil is the EFFECTIVE LATENT HEAT.

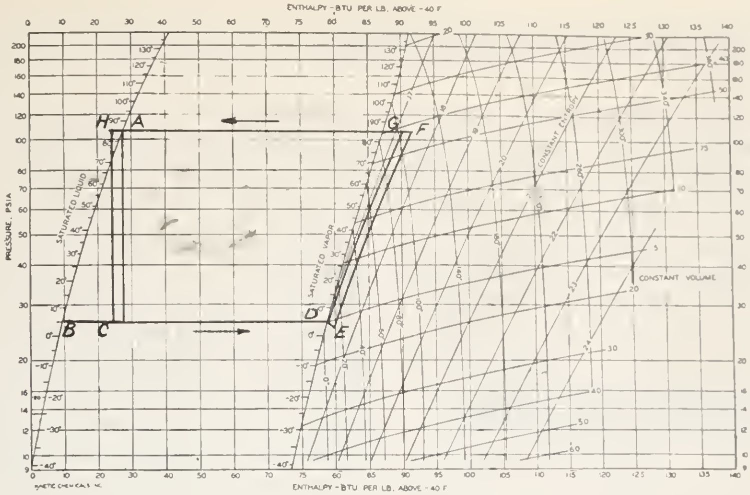
The refrigerant gas formed on evaporation passes down the suction line; as it does so it remains at almost the same pressure but it usually warms up somewhat (about 10 F.). The condition of a gas warming up after it has vaporized is called superheating of the gas. The degree of superheat is the temperature difference between temperature of the gas at the compressor and its corresponding pressure.

The compressor then takes the slightly superheated gas and converts it into a high temperature, high pressure gas; the temperature sometimes becomes as high as 180 F. depending upon the refrigerant and conditions. The gas is still in the gaseous state, and the increase in temperature means that the gas is more superheated than ever.

This superheated gas passes to the condenser and loses its heat to the air or water and cools down to its vapor pressure temperature. If the vapor pressure temperature is above that of the room, it starts losing some latent heat of evaporation; the quantity of heat it loses determines the amount of the gas that will condense into a liquid. After it has liquefied, the liquid cools down to room temperatures; then it goes on to the refrigerant control to have its pressure reduced, to be cooled, and to vaporize, thus repeating the cycle. See Fig. 21-39.

21-32. PRESSURE—HEAT CHART

To study the behavior of this refrigerant more accurately, we will base our discussions of it upon 1 pound of the refrigerant regardless of its state. The discussion will deal only with the pure refrigerant, neglecting the effect of lubricating oils and other influences. The chart, Fig. 21-40, shows the behavior of one pound of refrigerant in a refrigerating machine. The horizontal scale shows the amount of heat present in 1 pound of refrigerant at all times and under all conditions; whereas the vertical scale shows the pressure imposed upon it. This graph is commonly



21-40. A pressure-heat diagram for Freon-12. The saturated liquid curve represents the heat in the liquid at the various pressures before it will start vaporizing. The saturated vapor curve represents the division between the super heated gas and where the gas starts condensing into a liquid.
(American Society of Refrigeration Engineers)

called a pressure-heat chart. Using this chart as a basis for discussion, one will note that as the refrigerant vaporizes at a constant pressure it passes horizontally from B to D. This line indicates the vaporization of the refrigerant from a liquid into a gas in the cooling coil. The distance D to E represents the heating of this gas into a superheated condition as it passes down the suction line. Note that only a few Btu's of heat have been added. Point E is the condition the gas is in when it is taken by the compressor and compressed. Note how the pressure increases rapidly and how a few Btu's of heat are added to the gas. The gas is now considerably superheated.

Point F represents the condition of the gas as it leaves the exhaust valve of the compressor. The distance between F and G is the cooling of this superheated gas down to the point where it starts to condense. The line G to A represents the condensation of the refrigerant in the condenser from a gas into a liquid. Point A represents the amount of heat in the liquid and the pressure imposed on the liquid as it forms in the condenser. From A to H is the loss of heat from the liquid as it passes up the liquid line to the refrigerant control. Point H to C represents the throttling of the liquid upon passing through the refrigerant control, and the cycle is ready to be repeated for the one pound of refrigerant.

Note that the distance C to D does not represent the total LATENT HEAT of the liquid at the low side pressure condition. This means that F-12 which has a latent heat of 70 Btu per pound at 5 F. will not remove all of that heat from the cooling coil because some of it (approximately 19 Btu) is used to cool down the liquid refrigerant to the 5 F. temperature before it can vaporize. The 51 Btu remaining is called the EFFECTIVE LATENT HEAT or the EFFECTIVE REFRIGERATING CAPACITY.

This pressure-heat chart is an important graph of the physical property changes of a pound of a refrigerant as it passes around the refrigerant cycle.

A thorough knowledge of this chart is very helpful to the technician and to the service man.

21-33. PRESSURE—HEAT AREAS

The chart is divided into three main areas. To the left of the saturated liquid line all of the pound of refriger-

ant is liquid. See Fig. 21-41. Between the saturated liquid line and the saturated gas line the one pound is a mixture of liquid and gas. Close to the saturated liquid line, the pound is almost all liquid and close to the saturated gas line the pound area is superheated gas.

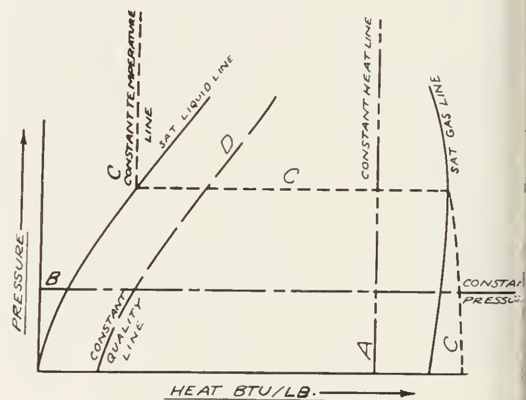
21-34. CONSTANT VALUE LINES OF PRESSURE—HEAT CHART

Many facts can be read from the chart, Fig. 21-42. Along any vertical line the heat in one pound of refrigerant is the same or constant. (A) Any horizontal line has the same or constant pressure, (B) The line along which the temperature reading is the same is almost vertical in the liquid area, is horizontal in the liquid-gas area, and slants down and to the right in the superheated gas area (C). Refrigerant quality means how much of the pound of refrigerant is liquid and how much is gas. Ten percent (10%) quality means the pound is 10% gas and 90% liquid. The line showing the quality at various pressures is shown at (D).

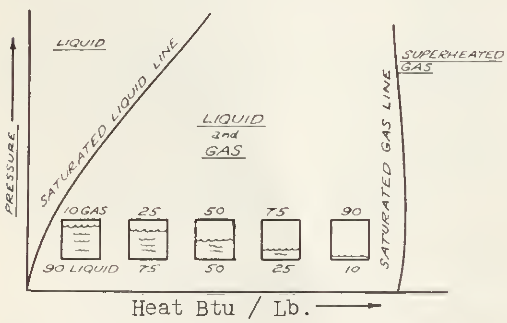
21-35. LATENT HEAT

The value of the latent heat of the refrigerant when vaporizing and when condensing in a refrigerating machine is different. At the lower pressure (vaporizing), as one may see from Fig. 21-43, the total latent heat to be added to the liquid to vaporize it is more than that needed to be subtracted to condense it into a liquid at the higher pressure. The explanation for this is that the liquid, when formed, is at a higher temperature than the liquid at the vaporizing pressure. This difference is represented by the specific heat of the refrigerant multiplied by the F. temperature difference for the two conditions.

The actual cooling or amount of heat removed is not equal to the latent heat of the refrigerant at the lower pressure but is somewhat less, and the actual heat removing ability is called the EFFECTIVE LATENT HEAT.



21-42. A pressure heat diagram. Line A indicates a constant heat condition with pressure change. Line B indicates a constant pressure line and the condition of the refrigerant with changing heat content. The constant temperature line C indicates conditions of equal temperature with changing pressure and heat.



21-41. A pressure heat diagram. It should be noted that as heat is subtracted the refrigerant becomes a liquid and as heat is added the refrigerant becomes a gas.

The effective latent heat of the refrigerant, when vaporizing, is the total latent heat at the low pressure minus the difference in the heat content of the two liquids at the high pressure and low pressure. This is because the high pressure liquid, when throttled in the refrigerant control, must be cooled down to the low pressure tem-

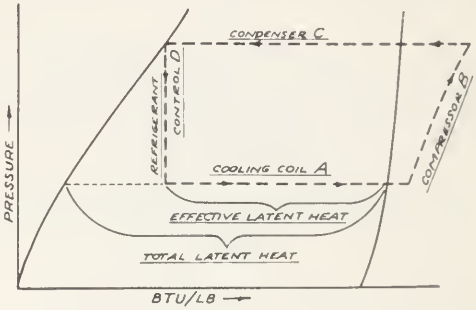
perature liquid before it can vaporize and remove heat from the surrounding substances. Part of the liquid vaporizes in order to cool its own liquid to the lower temperature. The gas formed during this operation is called "flash gas." The effective latent heat is an average value because the low side pressure varies somewhat during the operation of the system, due to the oil in the system, and because ideal conditions cannot be maintained. For F-12 the latent heat of vaporization at 5F. is 79 Btu per pound but its actual heat absorbing ability is only approximately 51 Btu per pound.

21-36. SATURATED GAS

A saturated gas is a gas in such a condition that if a little heat were removed from it, some of the gas would condense. An example of a saturated gas is illustrated in a refrigerant cylinder half full of liquid refrigerant. The gas in this space is saturated gas. This leads to another definition that saturated gas is a substance in a gaseous form in the presence of some of its own liquid. When the refrigerant vaporizes in the cooling unit, it is a saturated gas at first; but as this gas passes down the suction line to the compressor, it usually becomes warmer by 5 F. to 15 F. This additional heat and increase in temperature is called superheating the gas; that is, it is raising the gas above a saturated condition for this pressure, and the gas will now obey Charles' and Boyle's Laws.

21-37. SUPERHEATED GAS

A superheated gas is gas in such a condition that if some heat were removed from it, the volume of the gas would decrease, but there would be no condensation. The gas that the compressor handles is always superheated unless a condition arises wherein liquid refrigerant is admitted to the crankcase. The low pressure superheated gas, when it enters the compressor, is compressed; the energy, put into it by the compressor, increases the temperature and pressure on this gas tremendously. The amount of superheat is increased. This superheating of the gas lowers the efficiency of a machine and the less the superheating, the more efficient the machine will be. The heat added to the gas is the mechanical energy of the compressor being converted into heat energy; by knowing how much heat has been added, one may calculate the size of the motor necessary to drive the compressor.



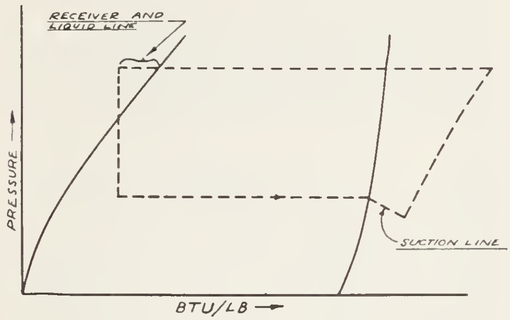
21-43. A pressure heat diagram. A. Liquid boiling in the cooling coil, the pressure and temperature are constant, heat is being added to the refrigerant. B. The compressor raises the pressure to the condensing pressure, the heat of compression is added and the temperature rises. C. The condenser cools the hot gas to the saturated gas line and then condenses it into liquid, the pressure is constant and heat is removed. D. The refrigerant control reduces the pressure very quickly, the temperature drops as some of the liquid refrigerant "flashes" into gas.

21-38. SPECIFIC HEAT

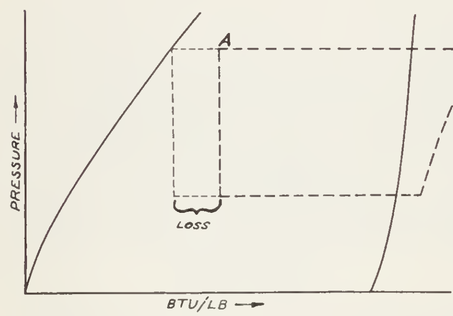
The specific heat of a substance is the amount of heat necessary to raise the temperature of 1 pound of that substance 1 F.

Substances may exist in three different states (solid, liquid, and gas). Every substance has three different values for its specific heat, depending

on whether it is a solid, a liquid, or a gas. The specific heat of the gas may be found subdivided into the specific heat under a constant pressure, or the specific heat under a constant volume. The specific heat of a gas under constant pressure is more than that of



21-44. A pressure heat diagram. The dotted line indicates the pressure-heat change through the refrigeration cycle.



21-45. A pressure-heat diagram showing the effect of insufficient refrigerant in the system.

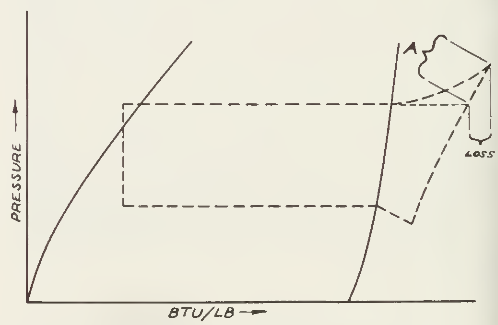
the same gas under constant volume, because when a gas is heated with a constant pressure being maintained upon it, the gas expands and does external work. This external work naturally necessitates an additional quantity of heat.

When a compressor compresses 1 pound of the refrigerant gas, it does not add heat to it under a constant pressure or constant temperature condition. This state of affairs in the compressor is called adiabatic compression, meaning that no heat has been removed from the gas as it was compressed. Actually a refrigeration compressor operates almost adiabatically because the compression takes place so rapidly.

The specific heat of liquid refrigerants varies considerably, depending on the pressure imposed upon them. The pressure to which the liquid refrigerant is subjected in the condenser, after it has condensed, must be determined to calculate how much heat must be removed from 1 pound of the liquid to further cool it to room temperature.

After the refrigerant passes through the throttling valve, it is subjected to a new pressure which is lower. One must now determine the specific heat of liquid under this new pressure to find out how much heat must be removed from it to cool it down to the vaporizing temperature.

If the liquid refrigerant is cooled before it is admitted through the refrigerant control valve, it will increase the efficiency of the system, Fig. 21-44. This device is incorporated in many water coolers and it is the reason for running the liquid and suction lines together. They are sometimes soldered together. These devices are called heat exchangers.



21-46. A pressure-heat diagram showing the effect of air in the system. A. Indicates the increase in head and exhaust value temperature.

21-39. EFFECT OF LACK OF REFRIGERANT

If the system is undercharged, the one pound of refrigerant does not

completely liquefy before it passes through the refrigerant control, (A) Figure 21-45. The result is two fold. First the effective latent heat is reduced by the amount indicated by the "loss" and more gas has to pass through the refrigerant control reducing its capacity and the extra quantity of gas increases the wear on the refrigerant control.

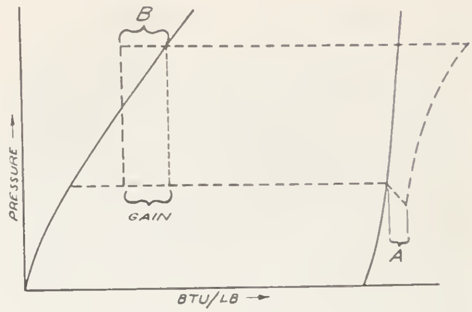
21-40. EFFECT OF AIR IN SYSTEM

Air in the system increases the total head pressure. However, the refrigerant will condense at the temperature and pressure as if it were in the condenser alone (Dalton's Law). The total head pressure being higher, the compressor has to pump the cylinder gas to a higher temperature and pressure, (1) Fig. 21-46. The additional heat added to this is a "loss." Also the cylinder head (especially the exhaust valve) and the top tube of the condenser will be at above normal condensing temperatures. These above normal temperatures also tend to cause the oil to deteriorate.

21-41. THE EFFECT OF HEAT EXCHANGER

The suction line gas as it leaves the cooling coil, travels down the suction line and into the compressor usually warms up somewhat, (A) Fig. 21-47. Because the low pressure gas picks up this heat in most cycles, it is more efficient to remove the heat from some part of the cycle. This heat exhange is done by putting the suction line gas in thermal contact with the liquid refrigerant just before the liquid goes into the refrigerant control.

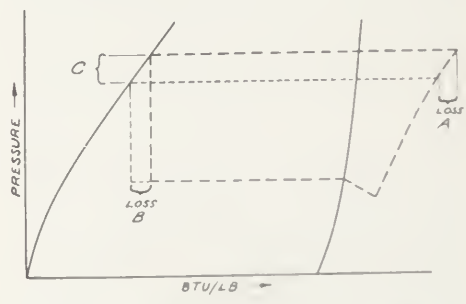
This action removes the heat at (B) and the result is a gain in effective latent heat and a reduction in "flash gas" which will increase the life of the refrigerant control.



21-47. A pressure-heat diagram showing the effect of the use of a heat exchanger. A. Shows a slight amount of decrease in intake pressure and temperature. B. Shows the amount of heat gain. In addition to the heat gain there is a reduction of flash-gas; this improves the operation of the refrigerant control.

21-42. EXCESSIVE CONDENSING PRESSURE

If the condenser is dirty (internally or externally) or if the condenser is undersize, the head pressure and temperature will be above normal, Fig. 21-48. The higher temperature conditions will cause the compressor to pump to this higher pressure and temperature and the extra heat of compression added is a "loss" (A). And if the liquid does not sub-cool to room temperature an additional loss is encountered in a decrease in effective



21-48. A pressure-heat diagram showing the effect of a dirty or undersize condenser or above average room temperature. A. Indicates the loss due to the unnecessary added heat of compression. B. Indicates a loss in effective latent heat of the liquid. C. Indicates a loss due to the work done to compress the gas at the higher pressure.

latent heat and an increase in flash gas (B).

21-43. COMPRESSOR CAPACITIES

As mentioned previously the compressor is the heart of the machine; it is the mechanism used to impart energy to the refrigerant to enable continuous refrigeration. The compressor is the means whereby the mechanical energy produced in the electric motor is converted into heat energy in the refrigerating machine.

The most efficient construction possible is to have a compressor built large enough just to handle the amount of refrigeration necessary. If the compressor is too large, energy is lost in excess friction, starting energies, etc. If the compressor is too small, it will not produce the amount of refrigeration required.

Basically, the compressor must remove the gas sufficiently fast from the cooling coil to enable the refrigerant to vaporize at low pressure. To do this it must remove the refrigerant vapor as fast as heat goes into the cooling coil and vaporizes it.

The method of determining the compressor size may be simply stated as follows: A cooling coil is designed to remove a certain amount of heat over a 16 hour running period; this amount being dependent upon the factors described in previous paragraphs. Let us say that the effective heat removing ability of the refrigerant is 50 Btu per pound, meaning that as each pound of refrigerant vaporizes in the cooling coil it picks up exactly 50 Btu of heat from the coil itself. To remove this amount of heat from the coil, the compressor must handle all the gas formed. Refrigerant tables give us values called specific volumes. These specific volume values mean that at that certain pressure 1 pound of the refrigerant vaporizing will form a certain number of cubic feet of gas. For example, if 1 pound of F-12 vaporizing at 9.17 psi pressure and 0 F. forms 1.637 cubic feet of gas in 10 minutes, the compressor, in order to remove the same amount of heat from the cooling coil during the period that the cooling coil removes its heat from the cabinet, must remove the 1.637 cubic feet of gas in 10 minutes.

How large a compressor is needed to do this depends upon the following compressor factors: the volume pumped per stroke of the piston, which is dependent upon the bore, stroke, number of cylinders, the speed of the compressor in revolutions per minute, and the volumetric efficiency.

As the crankshaft of the compressor completes one revolution, the piston reaches the lower dead center of its travel, and the low pressure gas fills up the space between the top of the piston and the head of the cylinder. As the crankshaft completes its revolution, the piston compresses this gas and pushes it through the exhaust valve into the high pressure side of the system. The volume handled in each case is the volume displaced by the piston as it moves from upper dead center to lower dead center. This volume may be calculated by the following formula.

$$V = \frac{\pi \times D^2 \times S \times N \times R}{4}$$

V = Volume in cu. in.
S = length of stroke in in.
D = Diameter of cylinder
N = Number of cylinders
R = R.P.M.

This formula simply calculates the area of the piston head $\left(\frac{\pi D^2}{4}\right)$ and then multiplies it by the length of the stroke producing the displacement volume in cubic inches. Now, if this is multiplied by the number of cylinders used, and the revolutions per minute of the compressor, the total volume in cubic

inches pumped per minute will be obtained.

Example: How much gas will a 2 cylinder compressor pump if it has a 2 inch bore, a 2 inch stroke and operates at 400 R.P.M. Using the above formula:

$$V = \frac{\pi \times D^2 \times 2 \times 2 \times R}{4}$$

$$= \frac{3.1416 \times 4 \times 4 \times 400}{4} = 3.1416 \times 4 \times 400 = 3.1416 \times 1600 = 5026.56 \text{ cu. in./min.}$$

$$= 3.1416 \times 2 \times 400$$

$$= 3.1416 \times 800$$

in cu. ft., the volume is (1728 cu. in. = 1 cu. ft.)

$$V = \frac{5026.56}{1728} = 2.95$$

$$= 2.95 \text{ cu. ft./min.}$$

Illustration problem:

Calculate the bore and stroke of a single cylinder compressor which, operating at 300 R.P.M., will compress the refrigerant gas formed by vaporizing 1 pound of sulphur dioxide at 0 pressure (5.2 cubic feet) in 10 minutes.

Solution:

$$V = 5.2 \text{ cu. ft.} = 5.2 \times 1728 \text{ cu. in. per cu. ft.}$$

$$= \frac{8985.6}{10} \text{ cu. in.}$$

$$\text{Volume pumped per min.} = \frac{8985.6}{10} = 898.56 \text{ cu. in.}$$

Using the formula

$$V = \frac{D^2 \times S \times N \times R}{4} = 898.56 \text{ cu. in.}$$

Compressors are usually designed with a bore equal to the stroke. So in formula becomes:

$$V = \frac{\pi D^3 \times N \times R}{4} = 898.56 \text{ cu. in.}$$

$$D^3 = \frac{898.56 \times 4}{300 \times 1 \times \pi} = 3.81 \text{ cu. in.}$$

$$D = S = 1.56 \text{ in. approximately.}$$

However, this value obtained is the theoretical amount of gas pumped by the compressor. Actually, the amount is much less and the actual amount depends upon the volumetric efficiency of the compressor. See next paragraph.

21-44. VOLUMETRIC EFFICIENCY

If a refrigerating unit is maintaining a 90 psi head pressure and a 0 psi low side pressure, the following things are evident: When the piston is on its upward stroke, it compresses this 0 gas until the pressure of the gas in the cylinder reaches 90 psi. When this pressure is reached, the gas should start passing through the exhaust valve into the condenser. However, in addition to reaching this high side pressure, it must overcome the exhaust valve spring tension or weight. This means an additional very slight increase in pressure.

Further, after the piston reaches upper dead center, there is still a little volume of the gas between it and the exhaust valve. This space is necessary because if no clearance were left between the two, when the piston came up it would pound against the cylinder head. This little volume of gas is under a high pressure of 90 pounds per square inch or more, and as the compressor piston goes down to receive a new charge of gas, this high pressure gas expands and partially fills the cylinder chamber. This residue gas decreases the amount of gas that may come into this chamber from the low pressure side of the system. This necessary space is called clearance volume. This volume varies between 4% and 9% of the piston displacement.

Also at speeds of 300 revolutions per minute or more, the piston is traveling so fast that the inertia or the inability of the gas to move fast enough prevents it from filling the cylinder chamber completely and losses are encountered in this manner. The difficulty gas encounters going through small openings, etc., is called wire drawing.

The pressure in the cylinder never gets as high as the pressure in the suction line. One can see from this that the higher the speed of the compressor, the less gas will be pumped per stroke.

Just as the exhaust valve offers a restriction to the gas flow, so does the intake valve with its tension and the weight of the valve parts.

The compressor runs at a relatively warm temperature and some of this heat warms the gas as it enters the cylinder, causing an expansion which also interferes with a complete load of gas entering the cylinder.

Other losses, such as the leaking of the gas past the piston and rings into the crankcase, etc., also explains why compressors cannot pump the amount of gas as calculated by using the bore and stroke formula.

The term, VOLUMETRIC EFFICIENCY, IS DEFINED AS THE RATIO BETWEEN THE VOLUME ACTUALLY PUMPED PER REVOLUTION DIVIDED BY THE VOLUME CALCULATED FROM THE BORE AND STROKE AND R.P.M.

For small compressors used in domestic refrigeration, having bores and strokes of 1 1/2-in. or thereabouts, the volumetric efficiency varies from between 40 per cent and 75 per cent with 60 per cent being a fair medium value. The larger commercial compressors depending upon their size and speed have volumetric efficiencies between 50 per cent and 80 per cent with 70 per cent being a fair value. The 60 per cent to 65 per cent volumetric efficiency should be used if the unit is air-cooled.

If the compressor explained in Paragraph 21-43 has a volumetric efficiency of 60 per cent the size of the compressor would be increased as follows:

As calculated in Paragraph 21-43
$D^3 = 3.81$

D^3 corrected $= \frac{3.81}{.60} = 6.35$ cu. in.

D corrected = 1.85 in.

or a bore and stroke of

1 7/8 in. x 1 7/8 in. would be required. Note that the correction for volumetric efficiency was made on the displacement volume of the cylinder and not on the calculated bore and stroke.

The volumetric efficiency of a compressor is very dependent upon the relative difference between the low side pressure and the high side pressure of the machine. For instance, in a F-12 machine when being used for domestic purposes, the compressor will be more efficient than if it were converted over into an ice cream system, because the decrease in low side pressure from 13 psi down to 0 psi with the same head pressure, reduces the actual pumping capacity of the compressor tremendously. The low pressure gas is expanded so that when the cylinder is filled at the low side pressure, only a very small amount, by weight, is represented. It may be judged from the various items affecting efficiency that increasing the head pressure, increasing the speed using thicker gaskets, and overheating the compressor will all reduce the compressor pumping ability.

21-45. MOTOR SIZES

The size of an electric motor necessary to drive a compressor in a refrigerating machine may be calculated on two basically different plans. (1) The horsepower of the motor may be calculated by determining the H.P. put into the compressor. This H.P. is based upon the speed of the compressor and the mean effective pressure (M.E.P.) of the gas in the compressor. (2) The size of the motor may be determined by using the amount of heat added to the gas in the compressor as the energy taken out of the motor.

21-46. MOTOR SIZES (MEAN EFFECTIVE PRESSURE METHOD)

The M.E.P. of the gas is the medium pressure bearing down upon the piston head, and it is the pressure to be overcome by the electric motor when driving the compressor. The M.E.P. is determined by a formula which uses as the basic variables the low side pressure, the high side pressure, and the ratio of the specific heat of constant pressure to the specific heat of constant volume $\frac{C_p}{C_v}$ for the kind of refrigerant. This formula is as follows:

$$M.E.P. = P_1 \times \frac{K}{K-1}\left[\left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} - 1\right]$$

P_1 = suction pressure, psia
P_2 = condenser pressure, psia

$K = \frac{C_p}{C_v}$ (1.20 for methyl chloride) See Chapter 8.

This value when multiplied by the area of the piston, by the length of the stroke, and by the R.P.M. will give the foot-pounds per minute needed to drive the compressor.

$$\text{Ft.-lb. per min.} = M.E.P. \times \frac{\pi D^2}{4} \times S \times N \times R$$

Convert the foot-pound per min. into H.P. by dividing by 33,000.

$$H.P. = \frac{\text{ft. \# / min}}{33{,}000}$$

The M.E.P. may be determined from the above or may be determined by obtaining the indicator card of the compressor being studied. Engineers handbooks set forth the methods of using and obtaining indicator cards.

For example: If the indicator card shows a M.E.P. of 30 pounds per square inch the indicated H.P. necessary to drive a 1 cylinder compressor with a 2-inch bore and a 2-inch stroke and running at 200 R.P.M. would be as follows:

$$H.P. = \frac{30 \times 2 \times 200 \times \pi \times 2^2}{12 \times 33000 \times 4}$$

$$= \frac{r x 8 x \pi}{3700 x 4} \quad \frac{10 \times \pi}{330} = \frac{31.416}{330} = .0952$$

or 1/10 H.P.

This is the theoretical H.P. and neglects friction, oil pumping, starting load, drive losses, etc. Up to a 1 ton machine one should double this H.P., i.e., 1/4 H.P. calculated will need a 1/2 H.P. motor. Up to 5 tons this ratio gradually tapers off to adding 30 per cent at 5 tons capacity to take into consideration the above losses. The reason for the decrease is that some of the losses remain constant, while others do not increase as rapidly in proportion to the increase in the size of the unit.

21-47. MOTOR SIZE (HEAT INPUT METHOD)

From the pressure heat charts, one can readily determine the amount of heat (Btu) added to a gas when compressed by the compressor. Referring to the F-12 pressure heat chart (Fig. 21-31), one will notice that approximately 10 Btu are added to the 1 pound of gas if the low side pressure is 1081 psi and the high side pressure is 93.2 psi gauge.

It is known that 2545.7 Btu per hour is equal to 1 H.P. and is also equal to 746 watts.

For example:

Calculate the H.P. required to drive the above compressor.

10.0 Btu are added per pound.

Suppose 1 pound of refrigerant is compressed in 2 minutes.

The Btu rate per hour $= \frac{10.0}{2} \times 60 =$ 300 Btu per hour.

The H.P. required (Btu method) $= \frac{300}{2546} = .117$

H.P. = 1/9 H.P.

This is the mechanical equivalent of the heat energy put into the gas; if the compressor friction were 0 and the belt drive were 100 per cent efficient, this would be the size of the motor necessary to drive the compressor. However, one must add about 50 per cent to this value to allow for compressor friction and belt efficiency. This would require about 1/6 H.P.

21-48. MOTOR DRIVES

Three means have been used for connecting the electric motor to the refrigerating compressor. In their order of popularity, these are: the belt drive, the direct drive, and the gear drive. The belt drive may be further subdivided into a single V-belt, single flat belt, and multiple V-belt. The multiple V-belt is the most popular drive at the present time, and from two to ten belts are used as the driving medium with two to four belts being the most prevalent. This method of drive, when correctly adjusted, is between 95 per cent and 97 per cent efficient. This type of drive will maintain its efficiency over a greater range of belt tautness than any other drive; because of this and because the belt will not jump, it is the most generally used.

Direct drives are universal in hermetic units regardless of their size and have been used frequently in small conventional units. The drive is very efficient, but such factors as the difficulty of alignment, the excess torque load due to seal pressure, and because of the drop in volumetric efficiency of the compressor at the higher motor speeds, most companies prefer the slower belt-driven unit. Several manufacturers are now producing directly driven compressors and have very successfully overcome many of its natural drawbacks. A gear-driven compressor is a very positive means of drive, eliminating such troubles as belt slippage and wear, but the increase in cost due to gear lubrication and casing, and the matter of gear noises have almost completely eliminated this type of machine from the refrigerating market. On farms and other places, where electricity is not available, commercial units are typically driven by means of a gasoline engine. This gasoline engine drive is usually connected by means of V-belts to the compressor, but they are also being directly connected.

21-49. MOTOR EFFICIENCY

Theoretically, an electric motor should produce 1 H.P. of mechanical energy for every 746 watts of electrical energy put into it; that is, a 1 H.P. electric motor on a 110 volt circuit should only consume 6.8 amperes. This situation, however, is not encountered because of bearing friction, magnetic eddies, magnetic air gaps, and power factor. The efficiency of the motor is the mechanical energy delivered at the motor shaft divided by the power input to the motor. For small domestic motors of approximately 1/6 H.P., the efficiency of the motor is only 40 per cent to 60 per cent, and for 1 H.P. to 2 H.P. the motor efficiency increases to from 75 per cent to 80 per cent. As the size of the motor increases, the efficiency increases; this is due to the fact that friction losses and air gap losses remain practically constant regardless of the size of the motor. Motors with an efficiency of 95 per cent to 98 per cent are common in the large sizes.

21-50. MOTOR OVERLOADS

In the conventional system in addition to maintaining compressor speed against certain resisting factors, the motor must take the compressor from an idle position and bring it up to its

rated speed. The energy necessary for this is greater than that necessary to maintain the compressor at this speed. This load is called the starting load, and is anywhere from 50 per cent to 100 per cent larger than the load imposed upon the motor when running. This load is due to the acceleration force imposed by the moving parts of the compressor which is termed inertia; that is, all bodies resist a tendency to change their speed of motion, and this resistance depends upon the mass and the rapidity of this change of speed. A motor which consumes 4 amperes when running normally will consume as much as 7 and 8 amperes when starting. In other words, a 1/3 H.P. motor when starting up sometimes will develop as much as 2/3 of a H.P. in order to overcome the compressor inertia and bring the compressor to its speed. This is a 100 per cent overload and must not be carried for any length of time.

21-51. CONDENSER CAPACITIES

The calculation of the capacity of a condenser is similar in many ways to the problem of computing the capacity of a cooling coil. The condenser must dissipate the heat from the gas fast enough so that just as much gas condenses in the condenser as is being pumped into the condenser by the compressor in a given unit of time. When this condition is reached the head pressure will build up until the temperature rises to the point where the heat dissipated will equal the heat put into the condenser. The problem of computing the capacity of the condenser varies according to the type of condenser being used. Condensers may be divided under the following headings:

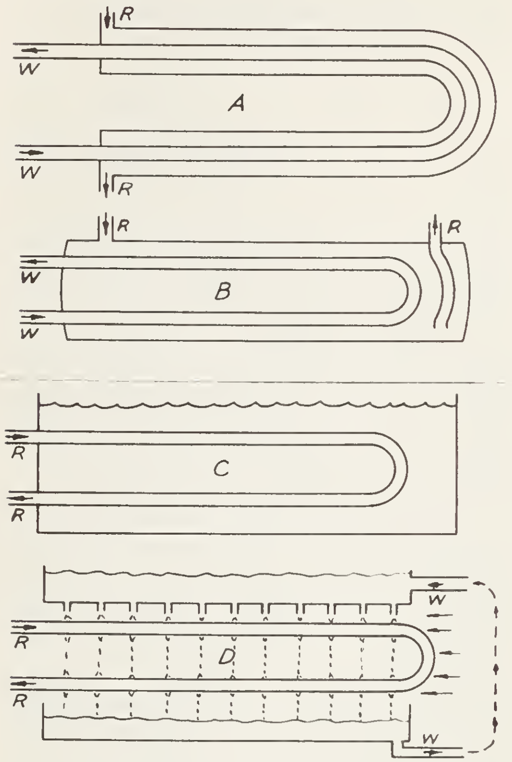
1. Air cooled:
   (a) Plain tubing
   (b) Finned tubing
   (1) Natural convection
   (2) Forced convection
2. Water cooled:
   (a) Liquid receiver type
   (b) Tube-within-a-tube type
   (Tube and shell type)

21-52. AIR COOLED CONDENSER CAPACITIES

The capacity of an air-cooled condenser may be calculated from one of two basic values. Some prefer using the total external area of the condenser to compute its heat dissipating ability, while others base computations upon what is called the frontal area of the condenser. Using the total external area of the condenser, the capacity of the condenser for dissipating heat depends upon the following variables: (1) external area, (2) temperature difference, (3) time, (4) air velocity.

Using these values the capacity of an air-cooled condenser varies between 1 Btu per square foot per F. per hour and 4 Btu per square foot per degree temperature difference. The effect of air velocity is to increase the condenser's capacity with an increase in air speed. The fans used to do this work are generally mounted on the motor shaft, and drive the air through the condenser at speeds between 400 to 1,000 feet per minute. When a fan of 400 feet per minute is used, the 2.5 Btu per square foot per F. per hour value will be found satisfactory, and this value will increase up to approximately 4 Btu with a 1,000 feet per minute air velocity. The calculation of the area of a condenser is identical to that for a finned coil (Paragraph 21-19). A single tube condenser has a total area of approximately 20 times its frontal area. For example: If a condenser has 10 square feet of surface with an air velocity of 400 feet per minute, what must be the refrigerant temperature to dissipate 5,000 Btu per hour if the room temperature is 75 F.?

10 x 2.5 x temperature diff. = 5,000
25 x temperature diff. = 5,000
Temperature diff. = 200 F.
Refrigerant temperature = 200+75 = 275 F.



21-49. Types of heat exchangers using liquids (water) as one of the liquids. A. Tube within a tube; B. Shell and tube; C. Tank; D. Baudelot R = Refrigerant; W = Water.

The same problem using a 50 square foot condenser.
50 x 2.5 x temperature diff. = 5,000
125 x temperature diff. = 5,000
Temperature diff. = 40 F.
Therefore, the refrigerant temperature = 115 F.
The same problem using a 75 sq. ft. condenser.
75 x 2.5 x temperature diff. = 5,000

$$\text{Temperature diff.} = \frac{5{,}000}{187.5}$$

Temperature diff. = 26.7 F.
Therefore, the refrigerant temperature = 101.7 F.

The heat to be removed by the condenser for each pound of gas is the heat content of the gas, when it leaves the compressor, minus the heat of the liquid at the condensing pressure.
Example:

In the illustration (Fig. 21-40), the gas has a heat content of 90 Btu when it leaves the condenser, and the heat to be removed by the condenser is this value minus 28 Btu, the heat of the liquid at 86 F. (temperature at condensing pressure).
90-28 = 62 Btu per pound of refrigerant condensed.

From an understanding of the refrigeration cycle, one may realize that if a condenser is under capacity, the compressor head pressure will rise in proportion in order to dissipate the required amount of heat; therefore one may put condensers of various sizes on the same compressor. If too small a condenser is used, a decrease in compressor efficiency, an increase in motor load, and a decrease in the life of the unit will result. The examples above illustrate this principle.

When the capacity of the condenser is based upon frontal area, it is claimed that the air being blown through the condenser is removing heat only from that surface which it strikes directly, and that the turbulent flow against the rear surfaces makes the heat removal from these surfaces negligible. The capacity per square foot of frontal area naturally is greater than the value stated above, and is between 6 to 10 Btu per square foot per F. per hour, depending upon the air speed. For air-cooling the dry bulb temperature of the room should be used.

Natural convection (static) condensers are becoming popular in the domestic refrigeration field. Several manufacturers are producing units which utilize a motor and compressor design inside a steel dome. This necessitates a separate motor to force air

through the condenser. To eliminate this motor, some companies are building large natural convection condensers mounted on the back of the cabinet. The size of these condensers is sufficient to permit cooling without the need of forced draft. The heat removing ability of these is approximately 1 Btu per square foot per F. per hour.

21-53. WATER COOLED CONDENSER CAPACITIES

The capacity of a water-cooled condenser is very high due to better heat contact between the cooling medium and the refrigerant for either the liquid receiver type or tube-within-a-tube type. The capacity will vary some with the type of water-cooled condenser used, Fig. 21-49.

The heat transfer varies directly as the amount of water passed through the condenser. If the flow is fast more heat will be removed, and if the water flow is slow the heat removal will be less. At 50 feet per minute water will remove about 185 Btu/sq. ft./hr./F. At 200 feet per minute, the water will remove about 330 Btu/sq. ft./hr./F. The heat removing capacity of these varies between 30 and 50 Btu per square foot per F. per hour in the smaller machines. For machines of a ton capacity or more, this value may be increased up to 90 Btu per square foot per F. per hour.

In addition to this heat removal, one must also calculate the air-cooling surface of the condenser, such as the external area of the shell, or the external area of the refrigerant tubing in the tube-within-a-tube type, to reach the correct capacity. In water-cooled systems, velocity of the water must be taken into consideration because with an increase of water flow or velocity, efficiency is increased. The method of determining the temperature difference between the cooling medium and the refrigerant is to use, as the refrigerant temperature, the saturation temperature of the refrigerant according to the head pressure obtained. Water temperatures should be taken as the average between the water-in and water-out temperature. For example:

A shell type water-cooled condenser has to remove 5,000 Btu per hour. How much tubing 3/8 O.D. must be put into the receiver to remove this heat if the water supply is 70 F.? The outlet water is 80 F. How many gallons of water per hour must be circulated? Consider the refrigerant temperature at 100 F. Assume the heat removing capacity of the condenser to be 40 Btu per square foot per F. per hour.

Tube area =

Condenser capacity = area (sq. ft.) x temp. diff. F. x Btu rate x time.

$$5{,}000 = \frac{\pi\, 3/8 \;.\;.\;.\;.\;.}{144 \;.\;.\;.\;.\;.} \times 25 \times 40 \times 1$$

$$\frac{5{,}000}{25 \times 40} = \frac{\pi\, 3/8 \times \text{length (in.)}}{144} \text{ or}$$

$$\frac{5000 \times 144}{25 \times 40} = \pi\, 3/8 \times \text{length}$$

$$\text{or length} = \frac{5000 \times 144}{25 \times 40 \times \pi\, 3/8} = \frac{720}{\pi\, 3/8}$$

$$\frac{720}{3.1416 \times .375}$$

$$\frac{1920}{3.1416} = 611 \text{ in.}$$

= 51 ft. approximately

The amount of water circulated = sq. ft. x wt. x temperature difference = Btu

1 x wt. x 10 = 5000

wt. = 500 lbs./hr.

1 gal. of water weighs 8 1/3 lbs.

$$\frac{500}{8\ 1/3} = 60 \text{ gal. of water per hr.}$$

21-54. REFRIGERANT LINES

The liquid and suction lines on refrigerating machines must be of sufficient size to handle the amount of the liquid or the gas required. The method of calculating the capacities of

these lines is to determine the maximum velocity allowed in the line and then, knowing the amount of gas or liquid to be handled, the internal cross-section of the line may be easily calculated.

21-55. REFRIGERANT LINE CAPACITIES (LIQUID)

The velocities in the liquid line of a unit varies with the density of the liquid and with its viscosity. These velocities may vary between 50 to 200 feet per minute, depending upon the refrigerant used. For instance: Freon -12 should have velocities no greater than 100 feet per minute while methyl chloride may have velocities as high as 200 feet per minute.

For example: If 75 cubic inches of liquid were used a minute, the internal cross-sectioned area of the liquid line to keep the liquid line velocity at 100 feet per minute or below would be:

$$\frac{75}{100 \times 12} =$$

Cross-section area = .063 sq. in.

$$\text{The inside dia.} = \sqrt{\frac{.063 \times 4}{\pi}} = .285 \text{ in.}$$

Use a 3/8-inch O.D. tubing. It is very important that these refrigerant carrying lines be of sufficient capacity; the cost of increasing the tubing size is so small in comparison to the total cost of the machine, that there is no real necessity for calculating the size of these tubings to too close limits. At least a 50 per cent oversize of the tube is therefore recommended.

If the liquid line is too small or if there are too many restrictions in the liquid line, the pressure drop may be enough to reduce the capacity of the refrigerant control below the capacity of the cooling coil. Extremes of this condition are revealed by sweating or frosting liquid lines when excessive pressure drops occur due to partially clogged dryers, strainers, or pinched lines.

The pressure drop in liquid lines that carry Freon -12 is shown in Fig. 21-50. Note that if one tried to use a 1/4 O.D. liquid line for a 12,000 Btu/hr. or 1 ton load, that the pressure drop would be .42 psi per foot. A 100 foot equivalent length liquid line would then have a total pressure drop of 42 psi.

Load Btu/hr.	1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1 1/8"
3,000	.035						
6,000	.120	.011					
9,000	.250	.021					
12,000	.420	.036					
18,000		.075	.010				
24,000		.127	.016				
36,000		.260	.033	.012			
48,000		.450	.054	.020	.010		
60,000			.080	.030	.014	.009	
84,000			.150	.054	.025	.015	
120,000			.280	.100	.049	.028	.009
240,000				.350	.160	.095	.029
360,000					.340	.200	.058
480,000						.340	.100

21-50. The pressure drop in Freon-12 liquid lines based on the refrigerating load and the size of the line (o.p.). The value is to be multiplied by the equivalent length. (Bush Mfg. Co.)

If the normal head pressure were 125 psig. then the pressure in the liquid line near the thermostatic expansion valve would be 125-42 or 83 psig. At 83 psig. the boiling temperature is 79 F. and sweating might occur in a humid 90 F. room.

In large systems, one must take into account the amount of refrigerant stored in the liquid line. This amount also affects pressure based upon weight of the liquid (static head), Fig. 21-51.

Bends and fittings increase the resistance to the fluid flow. It is claimed that there is as much friction to flow in a 90 degree elbow as there is in 5 feet

1/4"	3/8"	1/2"	5/8"	3/4"	7/8"	1 1/8"
.015	.043	.086	.134	.202	.269	.458

21-51. Refrigerant charge in pounds per foot of liquid line. (Bush Mfg. Co.)

of straight tubing of the same size. The friction in bends, fittings, and the normal friction of fluid flow through the tubing must be calculated when figuring gas velocities.

Normal Capacity	ORIFICE DIAMETER SO_2	Methyl Chloride	Freon-12	Freon-22
1/2 ton	.03125 .093	.03125	.0625 to .109	.03125
1 ton	.0625- .125	.0625 .093	.078-.109	.0625
1 1/2 ton			.125	.109
2 ton	.109 .156	.109 .125	.156	.125
3 ton		.125	.209	.15625
5 ton				.209
10 ton			.2812	.219
15 ton				

21-52. A table of expansion valve orifice sizes and capacities.

Refrigerant	Allowable Velocities in Feet per Minute: Suction Line (Gas)	Condenser Vel. (Gas)	Liquid Line Vel. (Liquid)
Ammonia.........	4000-5000	5000-6000	100-250
Methyl chloride.	1000-2000	2000-2500	100-200
Sulphur dioxide.	1000-2000	2000-2500	100-200
Freon 12........	800-1800	1800-2250	80-100
Water..........	30-50 (Liquid)	....	100-250

21-53. A table of allowable refrigerant liquid and suction line velocities.
(American Society of Refrigeration Engineers)

21-56. ORIFICE SIZES

The size of the orifice opening, controlled by a needle, which is usually located in the thermal expansion valve, must be carefully calculated. Its size depends upon the shape of the opening, upon the viscosity of the liquid passing through it, and upon the pressure difference as the fluid passes through the orifice. These orifice sizes, however, become fairly standard for domestic and commercial machinery with orifice openings of 0.93-inch and .156-inch being adapted as most popular. If larger orifices are needed multiple installations of expansion valves are used. See Fig. 21-52 for a table of orifice sizes and capacities.

If the orifice is undersize (too small) the amount of refrigerant that can pass through the valve will not be sufficient and the coil will be starved. Also the cooling coil pressure will reduce too fast.

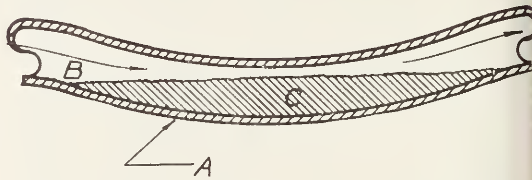
If the orifice size is too large, the valve will feed too much refrigerant too fast causing a "sweat back" or "frost back" down the suction line. The result will be a "searching or hunting" action causing alternate flooding and then starving of the cooling coil.

21-57. REFRIGERANT LINE CAPACITIES (SUCTION)

In a suction the gas velocity depends upon the low side pressure of the system and, therefore, in its application the velocities usually used are between 800 and 5,000 feet per minute. Figure 21-53. As the refrigerant evaporates in the cooling coil, its pressure must be somewhat higher than the gas pressure in the crankcase before it will go down the suction line. The compound gauge, mounted on the compressor, will show the compressor crankcase pressure which is lower than the actual pressure in the cooling coil. The suction line

involves two additional problems in the understanding of the pressure drop within the line. One additional complication is due to the necessity of returning oil to the compressor by means of the suction line. Also, when two or more coils are connected to one compressor, the resistances to flow in the different lines may cause the pressure on the surface of the refrigerant in the various coils to vary as much as 2 to 3 pounds per square inch. The friction in a 1/2-inch O.D. suction line is approximately .25-inch mercury (Hg) per 10 feet of length with a gas velocity of 1,000 feet per minute. This results in a problem of balancing cooling units. The amount of pressure drop becomes greater as the length of the suction line increases, as the cross-sectional area of the tubing decreases, or is in proportion to the number of bends and fittings in the suction line, Fig. 21-54.

The correct size of liquid and suction lines is very important in refrigerating units. An excessive pressure drop in a suction line is similar to operating the compressor at a lower pressure thereby reducing its capacity. For example, a pressure drop of 2 psi. at low temperatures -15 F. is the same as trying to operate at -20 F. and the condensing unit capacity is lowered approximately 12 per cent. The oil return should be taken care of by slanting the suction line consistently downward from the cooling coil to the compressor to permit the oil to drain naturally into the compressor. If a low spot is constructed into the suction line, the oil will accumulate here and decrease the cross-sectional area of the tubing, causing an orifice action which also decreases the efficiency of the gas flow, Fig. 21-55. Furthermore, when this low spot eventually becomes filled with oil, the pressure difference builds up and the oil is slugged into the compressor. This slugging of the oil in



21-55. Illustrating the restricting of gas flow due to oil collecting in a low spot in a suction line. A. Suction line; B. Refrigerant Gas; C. Oil.

the crankcase of the compressor accelerates oil pumping momentarily.

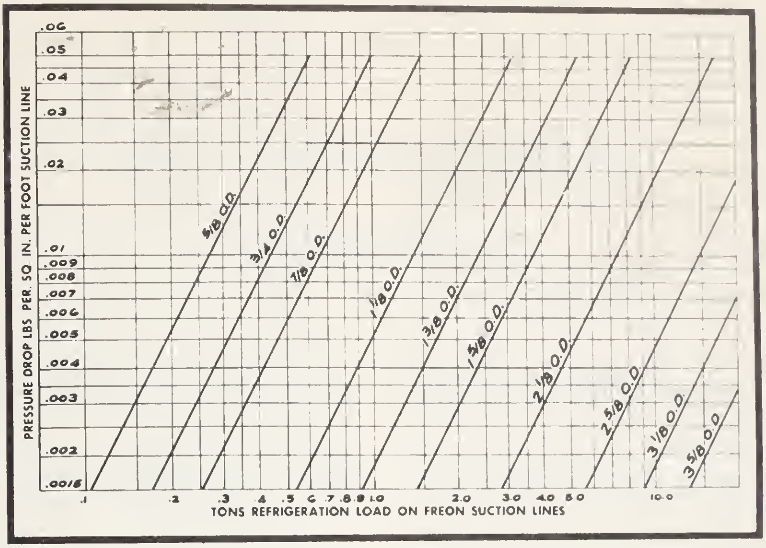
Fig. 21-56 shows the capacity of various sized suction lines using Freon -12 refrigerant. Note that a 1 in. nominal or 1 1/8 in. O.D. suction line can carry from 1/2 ton to 3 tons of capacity depending on the pressure drop. However, the best choice would probably be between .02 and .03 psi. pressure drop and this pipe should be used for 2 to $2\frac{1}{2}$ ton units. If the suction temperatures are lower or higher than 20 F., the pressure drops must be corrected because the denser gas has lower velocities and vice versa, Fig. 21-57.

One usually knows the capacity of the installation in Btu/hour or in tons of refrigeration. He can then estimate the correct suction line size by first getting an approximate size from Fig.

For Each	1/4	3/8	1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8	3 1/8	3 5/8	4 1/8
Valve	1.5	1.5	2	2	2.5	3.0	4.0	5.0	6.0	7.5	9.0	11.0	13.0	15.0
Elbow (90°)	.75	.75	1	1	1.5	1.5	2	2.5	3	4.0	5.0	5.5	6.5	7.5
Tee	1.5	1.5	2	2	2.5	3.0	4.0	5.0	6.0	7.5	9.0	11.0	13.0	15.0

21-54. A table of the ratio of resistance of valves, elbows and tees over straight length pipe. Note that a valve has as much resistance as 2 feet of 1/2 pipe.
(Bush Mfg. Co.)

PRESSURE DROP IN SUCTION LINES AT 20° SUCTION TEMPERATURE



21-56. A graph of suction line capacities for Freon-12 refrigerant. The suction line should be chosen between .02 and .03 psi per foot. The chart is based on 20F. If lower temperatures are used, coarser lines are needed and vice versa.

CORRECTION FACTORS FOR OTHER SUCTION TEMPERATURES										
Suction Temp	—40	—30	—20	—10	0	10	20	30	40	50
Correction Factor	2.70	2.28	1.90	1.62	1.38	1.18	1.00	0.88	0.75	0.64

21-57. A table of correction values for the pressure drops in a suction line. If the suction temperatures exceed 20F, the pressure drop is decreased, and if the temperatures are below 20F the pressure drop increases because the gas is less dense. The equivalent length is to be multiplied by the correction factor.

21-56 and then calculating the equivalent length of pipe from Fig. 21-54 and correcting for temperature using Fig. 21-57.

For example: to determine the suction line size for a 5 ton system at 0 F. Allow for a total 2 psi. pressure drop. The suction line has 30 feet of straight run, 6-90 degree elbows, 1-tee, and 1-valve, at 0 F. Assume that 1 1/8 O.D. suction line is to be used.

The equivalent length	30 feet
6 elbows x 2	12 feet
1 tee x 4	4 feet
1 valve x 4	4 feet
	50 feet

If a total of 2 psi pressure drop is desired, then,

$2 \div 50 = .04$ psi per foot.

However this line operates at 0 F. instead of 20 F. Therefore, $.04 \div 1.38 =$ .029 psi per foot.

Now referring back to Fig. 21-56, a 5 ton load with a .029 psi per foot pressure drop needs a 1 5/8 O.D. pipe for the suction line.

21-58. REVIEW QUESTIONS

Answers to the following questions may be found in Paragraph 21-59.

1. What is a Btu?

2. What is the Btu equivalent of a H.P.?
3. What is sensible heat?
4. What is latent heat?
5. What is specific heat?
6. Why is it important when calculating the heat load of a cabinet to know what the cabinet is used for?
7. Why is the heat leakage into a cabinet based upon the external area?
8. What is the purpose of a baffle?
9. Why must a horizontal baffle be insulated?
10. What materials were used for the interior walls of the older cabinets?
11. What is the purpose of the ice hold-over in the sweet water bath?
12. Why must a pressure type water cooler never be allowed to accumulate too much ice?
13. What is the specific heat of ice cream?
14. At what temperatures should brick ice cream be maintained?
15. How many pounds of walnut ice cream are there in a gallon?
16. What is meant by the superheating of the gas in the suction line?
17. What is the "effective latent heat" of a refrigerant? Why is it different from latent heat?
18. What causes the superheating of gas as it passes through the compressor?
19. Why may one use the Btu added to the gas as it goes through the compressor to calculate the size of the motor to drive the unit?
20. What is meant by volumetric efficiency, and what variables influence it?
21. What factors must be considered when determining the type of compressor drive?
22. What is meant by motor efficiency and what are the usual efficiencies?
23. Explain how heat travels from one carrying medium to the next, starting with the refrigerated cabinet and continuing to the suction line gas, describing the ease of transfer from one medium to the other.

21-59. CONDENSING UNIT CAPACITIES

The table, Fig. 21-58 lists the average hourly capacity of various sizes of condensing units. This clearly shows the increase in capacity of a condensing unit as the low side pressure increases providing the head pressure remains fairly constant.

AVERAGE COMPRESSOR CAPACITIES

	EVAPORATING TEMPERATURES °F							
	-30°		-15°		+20°		+40°	
	CONDENSING TEMPERATURE °F							
H. P.	110°	120°	110°	120°	110°	120°	110°	120°
2	5,200	4,500	9,100	8,200	18,000	16,800	22,800	21,200
3	9,000	8,300	14,300	13,200	22,100	20,800	36,300	34,200
5	14,200	12,500	24,800	22,400	41,700	39,300	62,400	58,500
7½	25,000	20,000	31,000	28,000	53,000	48,000	87,000	81,700
10	31,000	26,000	43,600	44,800	81,000	75,000	120,000	112,000
15	42,600	37,500	74,400	67,200	111,000	102,000	171,600	160,000
20	56,000	44,700	82,000	71,000	154,000	142,000	235,000	218,000
25	70,000	56,000	96,000	85,000	188,000	174,000	283,000	263,000
30	80,000	67,000	116,500	102,500	225,000	210,000	349,000	324,000
40	94,000	75,000	155,000	135,000	325,000	306,000	439,000	406,000
50	122,000	100,000	188,500	159,500	375,000	350,000	585,000	550,000
60	168,000	134,000	240,000	220,000	450,000	420,000	710,000	670,000
70	196,000	156,000	272,000	239,000	571,000	534,000	800,000	742,000
75	210,000	167,000	291,000	256,000	582,000	542,000	855,000	795,000
80	224,000	178,000	310,000	273,000	622,000	578,000	900,000	842,000
90	252,000	201,000	349,000	307,000	750,000	700,000	1,027,000	955,000
100	280,000	223,000	388,000	341,000	777,000	723,000	1,170,000	1,100,000

NOTE: The above figures are only approximate and based on catalog ratings of leading compressor manufacturers. For precise figures, refer to catalog of your compresaor manufacturer.

21-58. A table of condensing unit capacities when Freon refrigerants are used. (Kramer Trenton Co.)

Chapter 22

AIR CONDITIONING PRINCIPLES

People are continually endeavoring to improve their surroundings in order to increase the comfort of living. Among the more recent improvements we must consider air-conditioning as very important, for it deals with means of making the atmosphere in which we live and work more healthful and comfortable.

22-1. HISTORY

Man has always attempted to control the air in which he lives. In the northern and southern zones, heat is necessary to survive the winters, and man's finding of fire and his use of it to heat caves dates back beyond recorded history. In the tropic zones, man soon learned many ways to combat heat and high moisture conditions.

Heating was first done with an open fire, resulting in a smoky condition. The fireplace was a considerable improvement, and it enabled men to control the air flow through the fuel. The Franklin stove invented by Benjamin Franklin in 1760 was a tremendous step forward. Stoves were gradually improved until finally the furnace or one heat source for a multi-room building was built. All these heating systems required the burning of some fuel (coal, oil, or gas). We now have two heat sources that do not require flames. One is electric resistance or panel heating, and the other is the heat pump where the source of energy is an electric motor.

Comfort cooling has been accomplished with varying success for centuries: insulating the body with loose clothing to permit air circulation, the use of white clothing to reflect heat, the use of shade devices to reduce the heat from sun effect, all date back beyond recorded times. Cooling and removing moisture from the air, and removing dirt from the air date back approximately 50 years.

The science of air conditioning started when industry demanded better atmospheric control in factories that produced materials which were affected by temperature changes and moisture changes.

Dr. Willis H. Carrier (1876-1950) designed and installed a scientifically correct air conditioning system in a paper plant in 1902. By 1905 Dr. Carrier had perfected the spray type air conditioner for humidity control. He is credited with developing the differential thermostat and differential hygroscope. In 1911, Dr. Carrier published his Psychrometric Properties of Air Equations, and in 1919 he produced his Psychrometric Chart which is still the authority on air conditioning. The growth of air conditioning has been steady. Since the end of World War II comfort cooling has increased at a

Name	Chemical Symbol	DRY AIR Amount by Weight %	DRY AIR Amount by Volume %	AVERAGE AIR Amount by Weight %	AVERAGE AIR Amount by Volume %
Nitrogen	N_2	75.47	78.03		
Oxygen	O_2	23.19	20.99		
Carbon dioxide	CO_2	.04	.03		
Hydrogen	H_2	.00	.01		
Water	H_2O			X*	X*
Dust				X*	X*
Rare Gases		1.30	.94		

*Variable

22-1. Table showing the amount of the various gases and substances that make up normal air.

phenomenal rate. At present, over 1,000,000 air conditioning units are sold each year.

22-2. DEFINITION OF AIR CONDITIONING

The important factors involved in a complete air conditioning installation include:

1. Temperature control
2. Humidity control
3. Air movement and circulation
4. Air filtering, cleaning and purification

Complete air-conditioning provides automatic control of the above factors for all outdoor weather conditions for both summer and winter. Recently, cooling means have been developed for summer use in making residences, factories, railway coaches, theaters, office buildings, hospitals, and other structures more comfortable in the summertime.

In addition to the comfort phases of air-conditioning, certain industries have found that air-conditioning of their plants makes possible more complete control of manufacturing processes and therefore controls their finished product. Such industries include: printing, textile making, particularly artificial silk manufacturing, milling and baking, furniture, drug manufacturing and many others.

The first step in the direction of air-conditioning was in the development of the central heating plant. The second step was the development of automatic controls for regulating the heating plant. The final step was the development of automatic refrigeration devices which could be employed for summer cooling and dehymidifying the air.

A furnace only heats the air, a fan only moves the air, a cooling coil only cools the air, etc. The complete system must heat or cool the air, increase or decrease the humidity, control that air movement, and clean the air. All these functions are preferably done automatically.

22-3. AIR

Because conditioning deals with air, it is important that the structure and the properties of air be thoroughly understood.

The atmosphere surrounding the earth is reported to be about 400 miles thick. The atmosphere is divided into several layers. The ionosphere is the extreme outer portions of the air. The stratosphere is the layer between 50,000 ft. (10 miles) and up to 200 miles. The air we are most interested in is the layer between sea level and 50,000 ft.

The air in this space consists of a

mechanical mixture of gases. Each of these gases behaves as though it occupied the space alone (Dalton's Law). The mixture is composed of a mixture of gases listed in Fig. 22-1.

Because Oxygen (O_2) is a heavier gas, it has a higher percentage by weight than by volume. Hydrogen (H_2) is a very light gas, and it therefore does not show in the weight percentage but is shown in the volume column.

The water and the dust (all foreign bodies) are so variable in the air that they cannot be given any definite value in a table. However, these two substances in the air are of considerable importance in air conditioning.

Water exists in air under all conditions of temperature. It is in the gas form (vapor). It is present in the air even at temperatures below freezing, because it behaves as though it occupied the space alone, and therefore it is operating under extremely low pressures. For example, at .013 in Hg (very close to a perfect vacuum) steam can be made at -20 F., at 50 F. the pressure is .3624 in. Hg, and at 100 F. the pressure is 1.9 in. Hg. The amount of water (steam or vapor) in air is relatively small. For example, air at 72 F. and one half saturated with water vapor has 58 grains of water for each pound of dry air. As it takes 7000 grains to equal one pound, one can see that the water vapor accounts for approximately less than one per cent of the air. Also, dry air at 72 F. has a volume of about 13.34 cu. ft. per lb. which, if this same air is saturated (filled) to its maximum weight of water vapor, the volume will increase to 13.8 cu. ft. per lb. In a 50 per cent saturated case the volume will be 13.51 cu. ft. per lb. of dry air.

Therefore, the 58 grains of water vapor form 13.6 - 13.4 = .2 cu. ft. of volume. This steam will weigh $\frac{58}{7000}$ of a pound or .0083 pounds.

The impurities in the air come in a great variety of forms. Some of the different items which make up these impurities are:

1. Dust (solid particles 1 to 150 microns in diameter)
2. Fumes (.2 to 1 microns in diameter)
3. Smoke (less than .3 microns in diameter)
4. Bacteria (measured by culturing an exposed plate for 48 hours at 98 F.)

See PARAGRAPH 22-22 for more information on air contaminants.

1 micron = .00003936 inches or approximately $\frac{4}{100000}$ of an inch = .00004" = 1/2 of a $\frac{1}{10000}$. As one hair is $\frac{4}{1000}$, therefore 1 micron = $\frac{1}{100}$ of a human hair diameter.

1 micron = $\frac{1}{1000}$ millimeter

1 millimeter = $\frac{1}{1000}$ of a meter

1 micron = $\frac{1}{1,000,000}$ of a meter

1 meter = 39.36 inches

1 micron = $\frac{1}{25,400}$ of an inch.

Air has a comfort effect, a health effect, and a psychological or emotional effect on human beings. Therefore, air conditioning will become more and more important.

The air is practically invisible, but nevertheless it has weight meaning; it has inertia and density. It presses against the earth at sea level with a pressure of 14.7 psi. It has a density of .0725 lbs. per cu. ft. or .14 cu. ft. per pound.

Because of the mass of the air, it requires energy to move it, and it can exert pressures above atmospheric pressure. Also it requires energy to make air change its direction of motion.

Temp.	ICE, WATER, WATER VAPOR Sat.Press. in Hg.	Heat in Liquid B.T.U./lb.	Total Heat after Vaporization B.T.U./lb.	Vol. of Water Vapor cu.ft./lb.	DRY AIR Volume cu.ft./lb.	Specific Heat B.T.U./lb.	Amount of Water Vapor Saturate Grains
-40	3.790(10)-3	-177.1	1043.4	1.343(10)5	10..67	-9.61	.5508
-30	7.503(10)-3	-172.7	1047.8	7.441(10)4	10.820	-7.21	1.018
-20	1.259(10)-2	-168.2	1052.3	4.237(10)4	11.073	-4.81	1.830
-10	2.203(10)-2	-163.6	1056.7	2.475(10)4	11.326	-2.40	3.206
0	3.764(10)-2	-159.0	1061.1	1.481(10)4	11.579	0.00	5.480
10	6.286(10)-2	-154.2	1065.5	9060	11.832	2.40	9.161
20	.1027	-149.4	1069.9	5662	12.085	4.81	14.99
30	.1645	-144.4	1074.3	3608	12.338	7.21	24.07
32	.1803	-143.4	1075.2	3305	12.389	7.69	26.40
35	.2034	0.0	1076.5	2948	12.464	8.41	29.80
40	.2477	8.0	1078.7	2445	12.591	9.61	36.34
45	.3002	13.1	1080.9	2037	12.717	10.82	44.14
50	.3624	18.1	1083.1	1704	12.844	12.02	53.40
55	.4356	23.1	1085.2	1431	12.970	13.22	64.36
60	.5216	28.1	1087.4	1207	13.096	14.42	77.29
65	.6221	33.1	1089.6	1022	13.223	15.62	92.51
70	.7392	38.1	1091.8	868.0	13.349	16.83	110.4
72	.7911	40.1	1092.6	814.0	13.399	17.31	118.4
75	.8751	43.1	1093.9	740.0	13.475	18.03	131.3
80	1.0323	48.1	1096.1	633.0	13.602	19.23	155.8
85	1.2136	53.1	1098.3	543.3	13.738	20.43	184.4
90	1.4219	58.0	1100.4	467.9	13.854	21.64	217.6
95	1.6607	63.0	1102.6	404.2	13.981	22.84	256.4
100	1.9334	68.0	1104.7	350.2	14.107	24.04	301.5
120	3.4477	88.0	1113.3	203.2	14.612	28.85	569.0
140	5.8842	108.0	1121.7	123.0	15.117	33.67	1071.
160	9.6556	128.0	1129.9	77.27	15.622	38.48	2090.
180	15.295	148.0	1137.9	50.22	16.128	43.30	4598.
200	23.468	168.1	1145.8	33.64	16.632	48.12	16052.
212	29.921						

22-2. The vapor pressure, volume and heat values for water-vapor and low temperatures. Also the volumes and specific heat of dry air.

22-4. AIR TEMPERATURE

Air temperatures in which humans have had to exist vary from -55 F. as has existed in Montana to 120 F. in the shade in California and Arizona. The summer temperatures in the U.S. have exceeded 60 F. in all parts of the country except northern Maine and Washington state. The lowest temperatures in the winter have been below freezing in all parts of the U.S. except southern Florida and the southern portions of California and Arizona. The normal temperature is considered to be 72 F.

The human body temperature is normally 98.6 F., and since in the temperate zones the average atmospheric temperatures are below the body temperature, clothing is worn to conserve the body heat.

As heat is continually being generated in the body, heavy clothing in the winter insulates the body to retain the heat so we may be warm.

In the summer while the atmosphere is warm, it is often difficult for the body to radiate sufficient heat as it is generated.

The only way the human body can lose heat during those times when the air temperature exceeds 98.6 F. is by evaporation of perspiration from the body. As can be readily seen, this temperature change requires heating

the air in some instance, (winter and very cool earth zones) and cooling the air in some instances (summer and in torrid zones). The specific heat of day air is .24 Btu per pound, and energy is therefore needed to bring about these changes.

22-5. DRY BULB TEMPERATURE

Because human comfort and health depend not only on the air temperature but also on the humidity and the dust content in the air, one should not speak only of the air temperature but also of these other factors. In air conditioning the air temperature is listed more accurately as the dry bulb temperature (db) as this temperature is taken with the sensitive element of the thermometer in a dry condition. Unless otherwise specifically noted, all air temperatures are dry bulb temperatures.

22-6. AIR MOISTURE

The atmosphere we live in always has a water vapor content. Because the human body releases considerable moisture through its pores and by breathing (respiratory system), it is important that one know how air can absorb this moisture, and how the moisture in the air affects the release of moisture from our breathing mechanism and our pores.

Moisture in the air is in a water vapor form (in a gaseous form). It is invisible. Snow, sleet, hail, clouds, fog, and rain are forms of water vapor in condensed form.

It is important to remember that this vapor can exist in the air at below freezing temperatures.

The vapor behaves as if it existed or occupied the atmosphere all by itself. Therefore it has a temperature pressure curve like all volatiles. It also has a latent heat of vaporization and condensation, see Fig. 22-2.

As indicated in the table, the heat in the vapor is considerable, especially that amount of heat necessary to change the water or ice to steam and vice versa. The amount of heat is measured from 0 F. If one takes as an example 72 F., the air when dry has only 17.31 Btu/lb., but if the air were saturated with vapor, the total heat is 17.31 Btu/lb. $= 1092.6 \times \frac{118.4}{7000} = 17.31 + 18.48 =$ 35.79 Btu/lb. of dry water vapor to saturate it. Note that there is more heat in the vapor than there is in the dry air.

Air is very seldom saturated with water vapor. If it were, the human body could not lose heat by evaporation of moisture. Also the vapor in the air would be ready to condense if it contacted any material even a very little lower in temperature. Moisture would collect (condensate) on clothing, on walls, on grass, etc. People in this atmosphere would be covered with perspiration, and their clothes would be damp at all times.

Luckily the atmosphere rarely becomes saturated. To find out how much moisture is in the air, or how close it is to being saturated with water vapor, one may use a polished or shiny surface that can be slowly cooled. As this surface is cooled, it finally reaches a temperature at which a film of moisture appears on the surface (dew). If the temperature at which the surfaces "fogs" is noted, this temperature is the saturation temperature for the air sample. In nature, dew is the result of air becoming cooled to near its dew point temperature, and then as this air passes over the leaves and grass, small air currents and the pressure of the surface causes moisture to collect on this surface.

The dew point temperature can be measured or determined by placing a volatile fluid in a bright metal con-

tainer, then stirring this fluid with an air aspirator. A thermometer will indicate the temperature a mist or fog appears on the outside of the metal container. The slower the temperature is lowered, the more accurate the reading. One must be careful not to use flammable or toxic volatile fluids for this experiment.

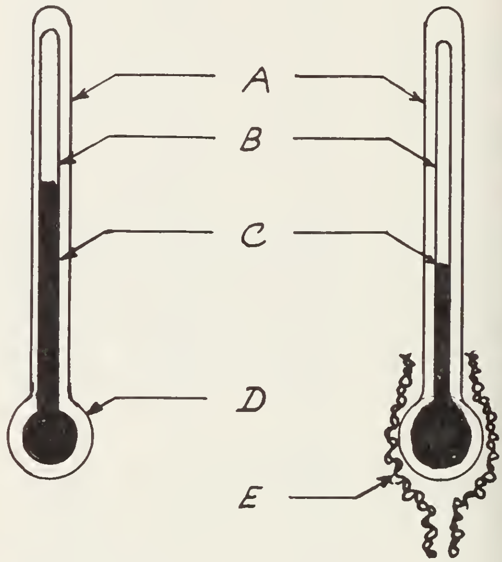
The dew point temperatures may be obtained more accurately by using instruments made especially for this purpose. See Fig. 22-3. This instrument can measure dew point temperatures from room temperature to as low as -80 F. The principle of operation is to pump a sample of the gas into the observation chamber of the instrument. The pressure is above atmospheric.

22-3. An instrument for determining the dewpoint temperature.
(Illinois Testing Laboratories, Inc.)

The pressure ratio gauge on the right adjusts for this pressure. Then manipulate the valve which rapidly exhausts the air and the lighted observation will indicate a fog if the gas sample is cooled to its dew point. This window is lighted and a "sunbeam" effect is noted if any fog exists. The pressure ratio determines the dew point temperature by formulation. The instrument is very accurate because the fog condition is very sensitive.

22-7. WET BULB TEMPERATURE

Another way to determine the moisture content of air is to use a wet bulb thermometer. This is a regular or standard thermometer except that its



22-4. A dry bulb thermometer and a wet bulb thermometer. A. Thermometers; B. Mercury column; C. Wet bulb column distance below dry bulb reading; D. Dry bulb; E. Wick over wet bulb.

sensitive element (bulb) is covered with a clean white cloth (wick), and this wick is wet with clean water, Fig. 22-4.

When the air is saturated with moisture, no water will evaporate from this bulb, and its temperature will be the same as a dry bulb thermometer near it.

However, if the air is not saturated, water will evaporate from the wick, and in doing so it will lower the wick temperature and therefore the sensitive bulb temperature. The heat will now flow from the air to the wet bulb which it surrounds.

The heat change is adiabatic; that is, no heat is gained or lost from

outside sources (radiation losses must be kept to a minimum). The total heat at saturation, (wet bulb temperature therefore equals the total heat in the original sample.)

$H_1 = H_2$

The accuracy of the wet bulb reading depends on how fast the air passes over the bulb, speeds up to 5000 ft./min. or 60 mi./hr. are best but dangerous if the thermometer is moved at this speed. Also the wet bulb should be protected from above normal heat radiation surfaces (radiator, sun, electric heater, etc.). Errors as high as 15 per cent may be made if the air movement is too low, or if too much radiant heat is present.

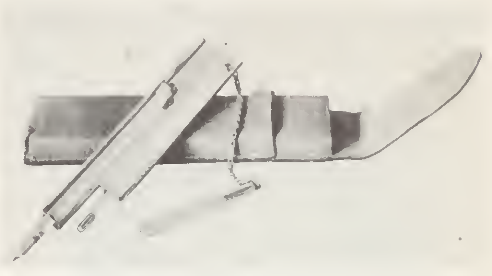
Relative air movement is usually obtained by whirling the thermometers on a handle provided for this purpose. Fig. 22-5 illustrates a pair of thermometers (wet and dry bulb) called a psychrometer. The wick should be clean and white. The shiny psychrometers come in a variety of sizes. Fig. 22-6 illustrates a portable shiny psychrometer with a carrying case.

22-5. A sling psychrometer. The wet bulb wick is mounted on the thermometer that extends the farthest (A) to the left.
(Friez Instrument Div., Bendix Aviation Corp.)

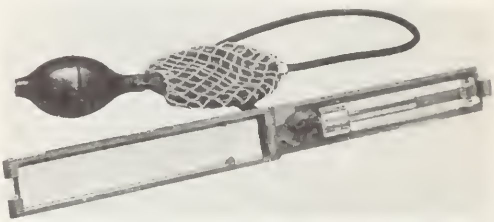
There are certain conditions in which it is difficult to spin the psychrometer such as narrow passages, etc. To obtain accurate results in these places an aspirating psychrometer is used, Fig. 22-7.

22-8. HUMIDITY

Humidity is a term used to describe the presence of moisture or water vapor in the air. The amount of moisture that the air will hold depends upon the temperature of the air. Warm air will hold more moisture than cold air. The amount of humidity in the air affects the rate of evaporation of perspiration



22-6. A pocket model sling psychrometer.
(Friez Instrument Div., Bendix Aviation Corp.)



22-7. An aspirating psychrometer. Note the handy calculating slide rule incorporated in the case.
(Friez Instrument Div., Bendix Aviation Corp.)

from the body. Dry air causes rapid evaporation, which cools the surface of bodies and makes it feel cool. Moist (humid) air prevents rapid evaporation of perspiration; thus one feels warm and depressed although the temperature as indicated by a thermometer may be the same in each case.

It is important to remember that this moisture is in the vapor form, and it is invisible.

Industrial processes and all air conditioning situations should have a record of the controlled temperature and humidity. Fig. 22-8 shows a seven day recorder for both temperature and humidity. Fig. 22-9 shows a 24 hour record of the temperature and humidity taken by a 24 hour recorder.

A different type of temperature and humidity recorder is shown in Fig.

22-10. The charts are printed on stiff paper, and the chart moves down as the recording proceeds. The humidity sensitive element is made of multiple human hair strands.

Air movement is an important part of the humidity effect on one's comfort. Moving air will improve the comfort even though the humidity is high.

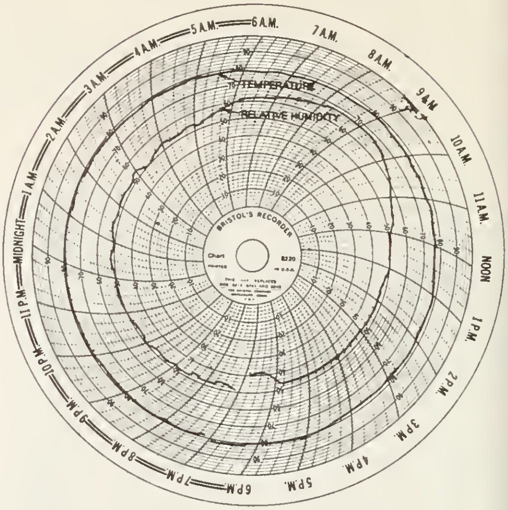
22-8. A seven day recorder for both the temperature and humidity. These records are important as a means of checking on the efficiency of the air conditioning system.
(The Bristol Co.)

Also, if there is no air movement, the air around the body will have a higher humidity than the rest of the air in the room, and a person will feel more uncomfortable.

Humidity is measured in two ways:
1. Absolute humidity
2. Relative humidity

22-9. ABSOLUTE (SPECIFIC) HUMIDITY

Absolute humidity is the actual amount of moisture in the air. The amount is measured as that amount that is contained in each pound of dry air. The amount of absolute humidity is measured in grains. One grain is 1/7000 of a pound. It can also be measured in terms of vapor pressure such as in inches of Hg. or in psi abs.



22-9. A chart from a 24 hour temperature and humidity recorder. Note how the relative humidity increased from 5 A.M. to 10 A.M.
(The Bristol Co.)

22-10. RELATIVE HUMIDITY

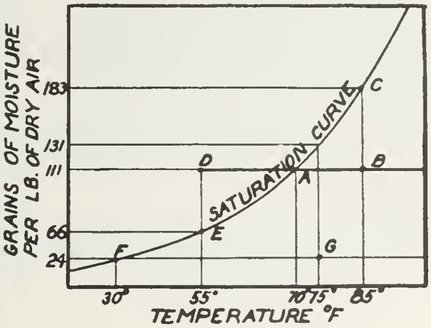
Relative humidity is a term used to express the amount of moisture in a given sample of air in comparison with the amount of moisture the air would hold if saturated at the temperature at which the sample was taken. Relative humidity is expressed in percentage as 30 per cent, 75 per cent, 85 per cent, etc.

Referring to Fig. 22-11 (Point B) contains 111 grains of moisture per

22-10. A temperature-humidity 10 or 30 hour recorder.
(Friez Instrument Div., Bendix Aviation Corp.)

pound of dry air. The saturated condition (Point C) for the corresponding temperature (85 °F.) will hold 183 grains of moisture per pound of air. The relative humidity for Point B 111/185 x 100 = 60 per cent.

Line A to B represents what happens when saturated air is warmed. Point D represents what happens when saturated air is cooled. The moisture represented by the distance D to E is condensed out of the air, since air at

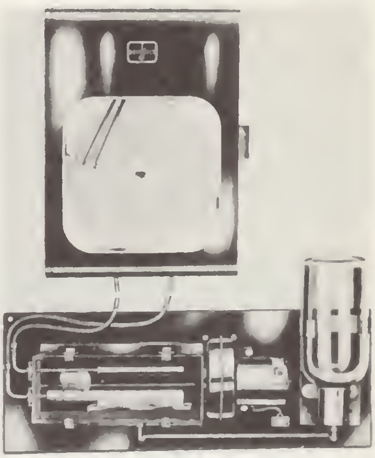


22-11. Illustration of a typical water vapor saturation curve for air. Note that as the temperature increases, the amount of moisture that the air will hold also increases.

the temperature corresponding to Point D (55 F.) will hold only 66 grains of moisture. The amount condensed is 111-66 = 45 grains.

A typical winter condition is represented by Point F. Saturated air is taken indoors at 30 F. and 100 per cent relative humidity. It holds 24 grains of moisture. If this air is heated to 75 F. and no moisture added, its new condition will be represented by Point G. The saturated condition for Point G would be 131 grains. Since the air has only 24 grains, the relative humidity is 24/131 = 18.3 per cent. This is too dry for comfort, as evaporation will take place rapidly from the body and nasal passages, and one is likely to feel cold. Actual winter conditions in homes are often much worse than this, as relative humidities of 8 per cent to 10 per cent are common.

Air movement is also an important factor affecting comfort. If cool dry air is circulated past a warm body, the heat flow from the body will be increased, which tends to cool the body. In the winter when a considerable difference in temperature exists indoors and outdoors, if there is no air movement within a room, the air may tend to stratify; that is, the cold air will sink to the floor and the warmer air rise to the ceiling. By providing a certain amount of air movement in the room the air will be stirred up so that a more or less uniform temperature will exist throughout the room. Air movement is usually accomplished by means of fans located in air-conditioners or in air ducts.



22-12. A seven day recording hygrometer. A small motor forces air over a dry bulb and a wet bulb. Note the bottle on the right. It is used to supply distilled water to the wet bulb wick.
(The Bristol Co.)

22-11. HUMIDITY MEASUREMENT

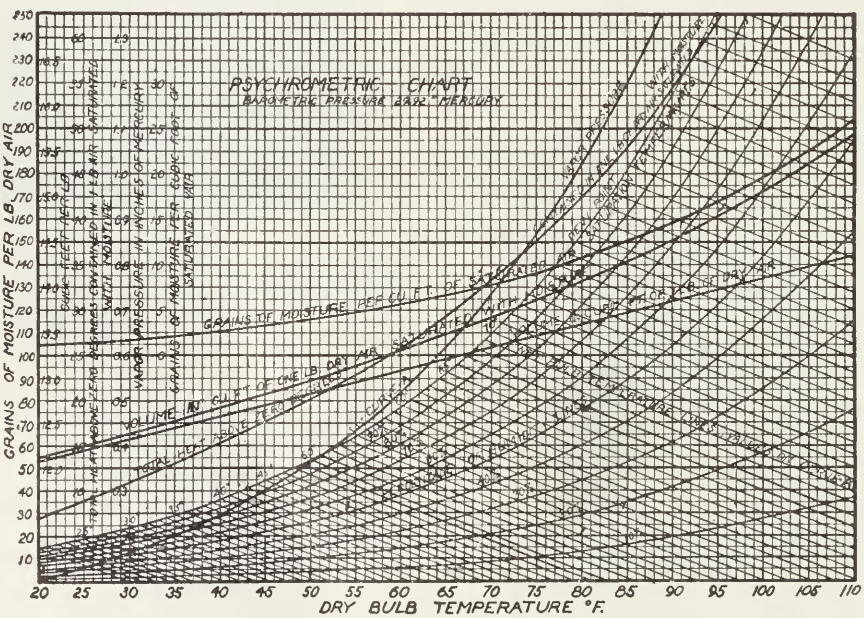
Relative humidity is measured by an instrument called a hygrometer. The simplest form of hygrometer consists of a wet and dry bulb thermometer. The wet bulb thermometer is merely an ordinary thermometer having a wick enclosing the thermometer bulb and

extending into a small water reservoir Fig. 22-12. As the wick soaks up water from the reservoir, it moistens the bulb of the thermometer, and evaporation of this moisture takes place. The evaporation removes heat from the thermometer bulb and cools it. This bulb is called the wet bulb. The wet bulb temperature, except in cases of 100 per cent relative humidity, will be lower for a given set of conditions than will the dry bulb temperature. It is evident that under conditions of very low humidity evaporation takes place rapidly from the surface of the wet bulb. This will result in a much lower wet bulb temperature, while under conditions of 100 per cent humidity no more moisture can be absorbed by the air and the two thermometers, wet and dry bulb, will read the same.

Tables and charts have been worked out using these two temperatures in order to arrive at the relative humidity for the conditions measured. Fig. 22-13. Charts which show the relation between wet bulb temperature, dry bulb temperature, and relative humidity are called "psychrometric" charts. Instruments may be used for measuring relative humidity other than the wet and dry bulb thermometers. Such substances as dry wood, human hair, and certain vegetable fibers have a great tendency to change their size or shape depending upon their moisture content, Fig. 22-14. If these substances are arranged in such a manner that air can circulate past them freely, they will absorb moisture from the air depending upon the humidity of the air and therefore respond to the atmospheric humidity. By connecting these substances to certain mechanisms, and by calibrating the mechanism, we are able to develop accurate hygrometers.

22-12. PSYCHROMETRIC PROPERTIES OF AIR

Psychrometry is the science and practice of dealing with air mixtures and their control. The science deals



22-13. A psychrometric chart.
(Carrier Corp.)

mainly with dry air and water vapor mixtures.

Psychrometry deals with the specific heat of dry air and its volumes. It also deals with heat of water liquid, heat of vaporization or condensation, and the specific heat of steam in reference to moisture mixed with dry air.

22-14. A home type hygrometer.
(Friez Instrument Div., Bendix Aviation Corp.)

Tables and graphs have been developed to show the pressure, temperature, heat content (enthalpy), and volume of air and its steam content. The tables and charts are based on one pound of dry air plus the steam to produce the air conditions being studied.

A standard pressure is used because the volumes of these gases vary rapidly with pressure changes; 29.921 inches of mercury (29.921 in. hg.) is used as the standard atmospheric pressure.

The charts and tables are properties of steam values with the specific heat of air added. The main curve of the chart is actually the pressure-temperature curve (saturation curve) for low pressure steam.

The tables are shown in Fig. 22-2.

One type chart is shown in Fig. 22-13.

22-13. PSYCHROMETRIC CHART

The psychrometric chart is a graph of the temperature-pressure relationship of steam. The horizontal scale (abscissa) the temperature, while the vertical side (ordinate) is the pressure scale.

The chart should be studied extensively, because it is a means for showing the various air conditioning cycles and the results of mixing air of various properties.

The various constant value lines are shown in Fig. 22-15.

Many of the air conditioning problems in this text will be solved using the psychrometric chart.

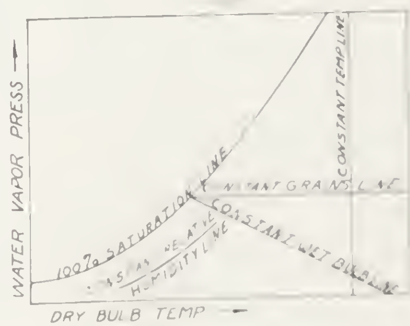
22-14. PSYCHROMETRIC TABLES

The table values permit much more accurate results because the values are accurate to four and five places. However, considerable arithmetic must be used to determine humidity values for air that is not saturated and other values.

One should become familiar with the use of both the chart and the table.

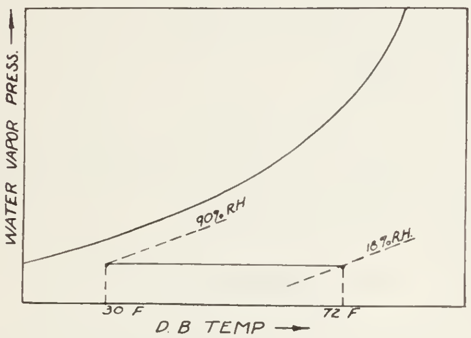
Some examples of the use of the graph or chart are included in the following paragraphs.

The values along the horizontal lines represent dry bulb temperatures



22-15. Psychrometric chart line nomenclature.

in F. The values along the vertical lines represent grains of moisture per pound of dry air. The 100 per cent humidity line or the line of saturation is indicated by A. The wet bulb temperatures are also indicated on curve A. This psychrometric chart may be used in connection with the wet and dry bulb thermometers to determine the relative humidity under any conditions.



22-16. A graph showing the decrease in relative humidity as an air sample is heated from 30 F. to 72 F.

Example: Given the dry bulb temperatures of 75 F. If the wet bulb temperature is 60 F., what is the relative humidity?

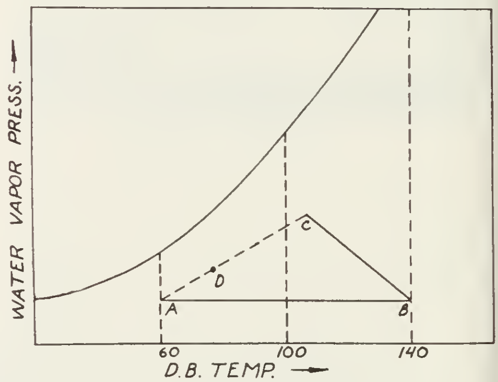
Refer to the psychrometric chart: the vertical line corresponding to the 75 F. dry bulb temperature crosses the oblique line corresponding to the 60 wet bulb temperature just above the 40 per cent humidity line - approximately 41 per cent.

The "dew" point is also indicated upón the psychrometric chart. This is the temperature below which, if a quantity of air is cooled, moisture will start to condense out. It also is the 100 per cent humidity point.

Example: What is the dew point for a sample of air in which the temperature is 80 F. and the relative humidity 60 per cent? Referring to the psychrometric chart, the point where the 80 F. line intersects the 60 per cent humidity line represents the quantity of moisture contained in each pound of air. If this air is cooled without a change in its moisture content, as represented by the horizontal line going through this point, it will be found that the horizontal line intersects the dew point line at a temperature approximately 64 F., which is the dew point for the sample under discussion.

22-15. HEATING CYCLE

The heating of a certain space means to warm the air from outside conditions to the correct indoor conditions. Assume the outdoor conditions are 30 F. and 90% R.H. Fig. 22-16

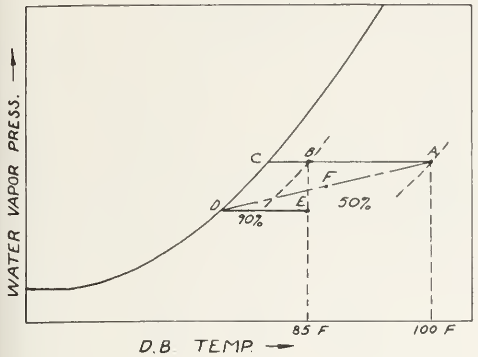


22-17. A recirculating warm air heating cycle on the psychrometric chart. A. Cold air return; A to B heating in the furnace; B. to C. Humidifying the air; C. to A. Mixing of air with room air; D. Final conditions after mixing.

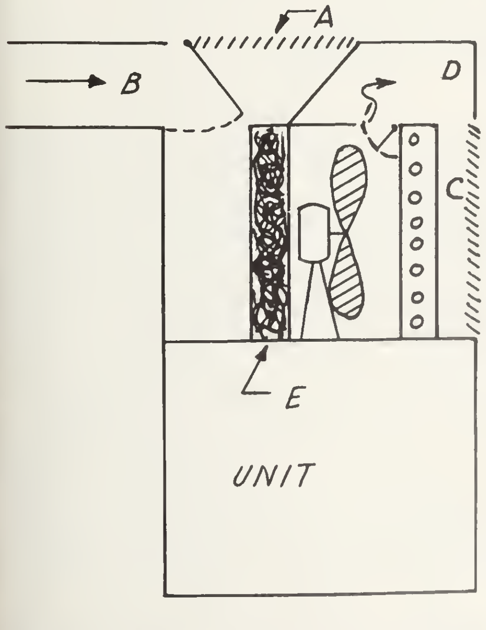
shows that the outdoor air as it comes into the building is heated at 72 F. No moisture is added, and therefore the heating is along a constant vapor pressure or grains of moisture line. This is typical heating path for air that filters into a house 12.4 cu. ft. to 13.45 cu. ft./lb. dry air. The heat increases from 10.6 Btu to 20.8 Btu/lb. of dry air, an increase of 10.2 Btu.

In a warm air heating device, assuming that the return to the furnace is 60 F. and is at 25% R.H., that the furnace heats the air to 140 F., that a

humidifier adds moisture to the warmed air, and finally that this heated air mixes with the air in the room. Fig. 22-17, A to B is heating the air, B to C, is this warm air passing over the humidifier (total heat is constant). Between C and A the heated and humidified air is mixed and the final result is at D.



22-18. The cooling cycle on the psychrometric chart. A. Condition of outside air; B. Partly cooled air; C. Air cooled to saturation; D. Air cooled to remove some moisture; E. Dehydrated air reheated; F. Result of mixing treated and untreated air.



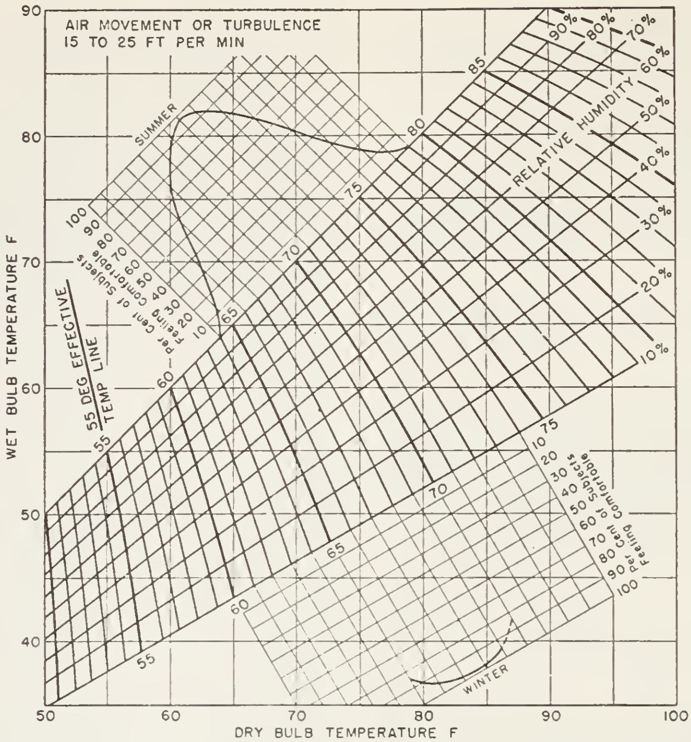
22-19. Air circulation in a console comfort cooling air conditioner. A. Recirculated air; B. Fresh air; C. Cooled air; D. Recirculated untreated air; E. Filter.

22-16. COOLING CYCLE

A cooling cycle is lowering the temperature (db) of the air. When this happens, Fig. 22-18, A to B, the relative humidity increases. Some moisture must therefore be removed. This moisture can be removed by using chemicals to dehydrate the air or by cooling the air up to the saturation curve and then removing the moisture by condensing moisture on the cooling surface (B to C to D). The distance from C to D is the drop in vapor pressure or grains of moisture removed. Reheating to E along a horizontal line to E will decrease the humidity. However, what more often happens is the air leaving at D is mixed with the room air which is at some intermediate condition between 85 F. and 100 F. The mixture meets on the line between D and A. If one third of the air by weight is passed through cooling coil, the mixer temperature will be one third of the way from D to A, that is to F. Some systems mix the air inside the air conditioner and also introduce fresh air into the air conditioner to obtain results as shown in Fig. 22-19.

22-17. COMFORT ZONE

As has been indicated, comfortable conditions result from a combination of temperature, humidity, air movement, and air cleanliness. However, one may have equal comfort under varying absolute values of these factors. For instance, the high relative humidity, which would tend to be oppressive, may be counteracted by a relatively low temperature; rapid air movement, or as is in the case of many homes in the winter time, a low relative humidity is compensated for by an increase in room temperature and a very slight air movement. Fig. 22-20 illustrates what is commonly accepted as the comfort zone for the above conditions. It will be noticed that



[a] *Note.*—Both summer and winter comfort lines apply to inhabitants of the United States only. Application of winter comfort line is further limited to rooms heated by central systems of the convection type. The line does not apply to rooms heated by radiant methods. Application of summer comfort line is limited to homes, offices and the like, where the occupants become fully adapted to the artificial air conditions. The line does not apply to theaters, department stores, and the like where the exposure is less than 3 hours. The summer comfort line shown pertains to Pittsburgh and to other cities in the northern portion of the United States and Southern Canada, and at elevations not in excess of 1000 ft above sea level. An increase of one deg ET should be made approximately per 5 deg reduction in north latitude.

[b] Dotted portion of winter comfort line was extrapolated beyond test data.

22-20. A graphical representation of a comfort zone. (American Soc. of Heating and Air Conditioning Engrs.)

this comfort zone represents a considerable area. However, experiments have indicated that any point in this area gives approximately equal comfort under equal conditions of clothing and work.

22-18. EFFECTIVE TEMPERATURE

While our studies so far would indicate that we should establish certain comfort zones of effective temperature in our residences and places of work, this is not entirely true due to the fact that we are not able to air-condition all outdoors and that a certain portion of our time must be spent outdoors. The human body is able to accustom itself only to certain changes in a given length of time. It, therefore, becomes necessary to so regulate air-conditioning equipment that it will give a certain degree of air-conditioning. While this will be comfortable in itself, it will not subject the person to too great a shock on entering this conditioned space, or when going out into the normal outdoor atmosphere. It may, therefore, be said that air-conditioning is, to some extent, a compromise between the actual atmospheric conditions and the ideal conditions as indicated in the comfort zone.

We compensate for some of these changes by clothing. For example, in the winter time we attempt to maintain

temperatures of approximately 70 F. to 75 F. indoors, although the temperature outside may be 0 F., which is a temperature difference of 70 F. This is because it is usually considered more comfortable to put on additional clothing when going outdoors under such conditions than to remain indoors with sufficient clothing to be comfortable at a temperature only a few degrees above zero. However, in the summer, the reverse of this is not true. We do not dress warmer when we enter a space conditioned to 70 F. when the outside temperature is 90 to 100 F. Instead of feeling comfortable on entering such a conditioned space, we may feel chilled and too cold. It is, therefore, important that a compromise condition be maintained which corresponds to some extent with outdoor temperature.

From Fig. 22-20, one can see that in the summer most people are comfortable between 72 F. db and 100 per cent rh up to 85 F. db and 10 per cent rh. During the winter most people feel equally comfortable between 66 F. db and 100 per cent rh and 74 F. db and 10 per cent rh.

22-19. AIR MOVEMENT

Air movement has a distinct effect on a person's feeling of comfort. If one resides in perfectly still air, he soon builds up the surrounding air to a higher temperature and a higher humidity. Likewise, if there is too great an air movement, over 15-20 feet/min., the wiping action of the wind produces an effective temperature below the actual conditions.

Air conditioning attempts to produce air movement in those spaces occupied by people, but not an annoying movement. However, the apparatus is designed to move the air as fast as possible in the rest of the air cycle. This air speed increase is due to first reducing the size of the air passageways (ducts and machine air passages), and second, to throwing the air as far as possible into the conditioned space (to reduce the number and size of the air openings in the room).

The air passage velocities are limited however, because if the velocity is too high, an air turbulance noise becomes very disturbing, and also the energy needed to move the air at high velocities (friction losses) becomes uneconomical.

The subject of air distribution is covered in more detail in Chapter 23.

22-20. DUCTS

To carry air to the air conditioning machine, through the machine, and then to deliver to the place of use, air passages must be built. These air passages are called ducts.

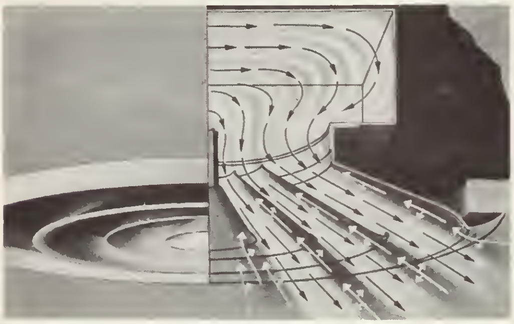
These ducts may be made of many materials. The pressure in them is very small, a 1 inch pressure rise is high and this pressure amounts to only $\frac{1 \times 14.7}{12 \times 34}$ approximately .03 psi above atmospheric pressure. The materials therefore only have to be strong enough to support their weight. Original air ducts were very thin tinned sheet iron (hot air ducts), then galvanized sheet steel, aluminum sheet, and finally insulated duct such as asbestos fibre board were developed. Passage-ways such as formed by studs or joists may be used where a fire hazard does not exist.

Three types of ducts are used as classified by their use: conditioned air ducts, recirculating air ducts, and fresh air ducts.

Although round ducts are the more efficient in reference to air flow square and rectangular ducts are the more popular, as they conform better to the design of building structures.

22-21. GRILLES

The end of a duct is usually covered with and concealed by a perforated covering called a grille. This covering may also be placed over the intake of a recirculated air duct or a fresh air duct.



22-21. A ceiling grille with specially designed outlets that produce air diffusion in the grille. (Anemostat Corp. of America)

The purpose of the grille is to prevent any large objects from getting into the duct and to provide a control for the direction of flow of the air into the room.

The grille is an extra resistance to the air flow. The grille cross section pieces block the air passage by approximately 30 per cent. For this reason, and also because they must use a slow air movement to reduce the noise, the duct cross-section is usually enlarged at the grilles.

Many forms of grilles have been designed. Some are fixed and direct the air only in one direction. Others are adjustable and can be arranged to direct the air in different directions. A popular grille design is shown in Fig. 22-21. This grille has circular segments and is designed to serve as a diffuser grille. The duct air by inertia flow along the upper surface of each truncated cone. This action reduces the pressure underneath each cone and room air enters and is mixed with the duct air. This diffusion mixes the entering air with the room air and produces a more comfortable condition.

22-22. AIR CLEANING

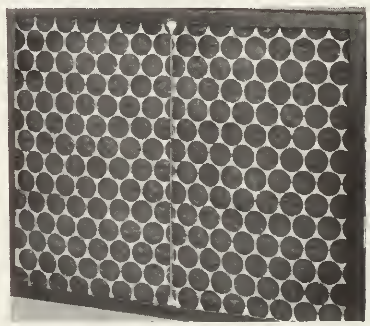
As important as the temperature, the humidity and the air movement, is the air cleanliness. The air contaminants, as all foreign matter is called, vary considerably in size and in material.

Solid particles, kept in suspension in the air by air currents, are commonly classified into three groups:

Dust is the result of wind, some sudden earth disturbance, or by mechanical work on some solid. Dust can have any origin; animal, vegetable or mineral.

These particles are usually over 600 microns in size (about .004 in. in dia.).

Fumes are solids formed by condensation and solidification of materials that are ordinarily solids but have



22-22. A fiber glass oil impregnated filter. (Pittsburgh Plate Glass Co., Fiber Glass Div.)

been put into a gaseous state (usually an industrial or chemical process). These particles are about 1 micron in size.

Smoke is the result of incomplete combustion so solid particles are carried into the atmosphere by the gaseous products of combustion. These particles vary in size from .1 to 1 microns.

Other forms of air impurities are the liquid impurities; these are known as:

1. Mists
2. Fogs

Mists are small liquid particles, mechanically ejected into the air by splashing, mixing, atomizing, etc.

Fogs are small liquid particles formed by condensation. Fogs indicate that the atmosphere has reached the saturation state for that particular chemical.

The third general classification of the air impurities consists of the impurities that act as true gases.

1. Vapors
2. Gases

There is little difference between these two impurities. Vapors are gases that have condensing temperatures and pressures close to normal conditions.

Not all impurities are objectionable or harmful. Perfumes and deodorizers have been used for years to either make the air more pleasant to be in or to conceal objectionable odors.

Special applications for air cleaning may be provided for

1. Pollen
2. Bacteria

However, the best air conditioning practice is to clean the air.

Pollen grains come from vegetation growth such as weeds, grasses and trees. Their presence in the air is usually responsible for hay fever, rose fever, and other respiratory conditions. The removal of these pollen from the air has been an important contribution of air conditioning. These particles vary in size from 10 to 50 microns.

Bacteria are micro-organisms and are responsible for the transfer of many diseases. Many manufacturing processes require the removal of these bacteria during the process. Also hospital rooms and even refrigerators may use bacteria removing devices.

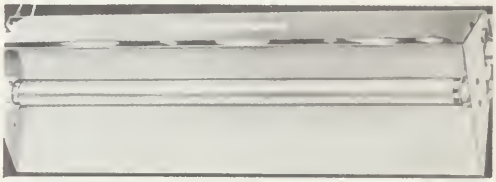
22-23. AIR CLEANING DEVICES

Many methods have been developed to clean the air. Solid impurities should be removed as completely as possible because these particles settle from the air and cover the furniture, carpeting, drapes, and floors with dust and frequent dusting must be done.

Some methods to remove these dust particles are:

1. Centrifugal devices
2. Air washers
3. Oil impregnated filters (Fig. 22-22)
4. Electrostatic precipitators

Mists or fogs are usually removed by heating to turn the mists and fogs into invisible gases or by condensing to remove the mists and fogs in the liquid state.



22-23. An ultra-violet lamp for elimination of bacteria and mold spores from the air.
(Ultra-Violet Products Inc.)

A condensation process may be used to remove vapors and gases.

Pollen grains may be removed by filters, or by using a wet surface to which the particles will adhere.

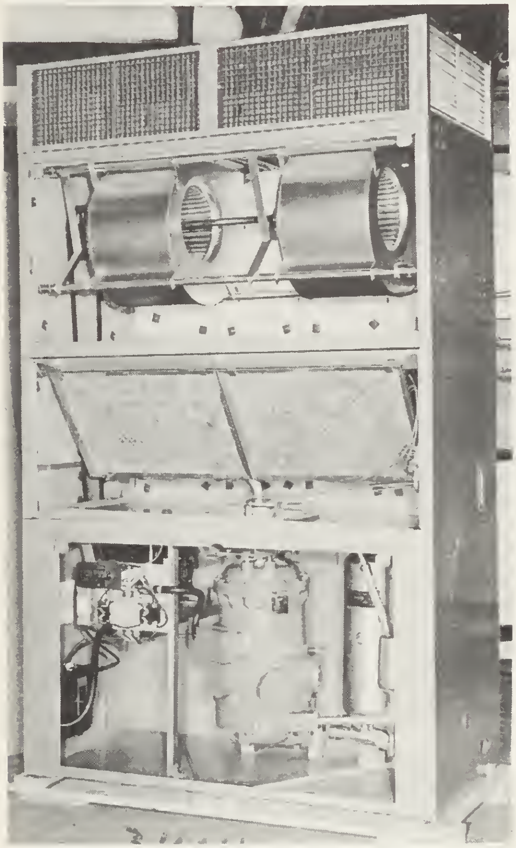
Bacteria can be removed either by filter chemicals or by a sterilizing light such as an ultra-violet light. An ultra-violet lamp used for air purification is shown in Fig. 22-23. The lamp is usually located to shine the rays upward. The lamps are mounted 6 1/2 to 7 feet high when turned up; they should be below eye level when turned down.

22-24. OIL FILTERS

The most popular filters are those

made of various fibers (glass, wool, etc.). These fibers are covered with some adhesive liquid. The air is made to change direction and speed with the result that the lint and dust contacts the adhesive surfaces and is trapped.

These filters will remove as much as 90 per cent of the dirt if they do not become saturated or if the air velocity is low enough. See Fig. 22-24. The more common filters are of the throw-



22-24. A typical fiber glass filter installation. (Airtemp Div., Chrysler Corp.)

away or disposable type. These filters should be renewed twice each year or more frequently if the dust conditions are high. The frames are usually made of cardboard wire reinforced. Fig. 22-25 shows a fiber filter being installed in a window air conditioner. The filter should be replaced if the pressure drop exceeds .5 in. of water.

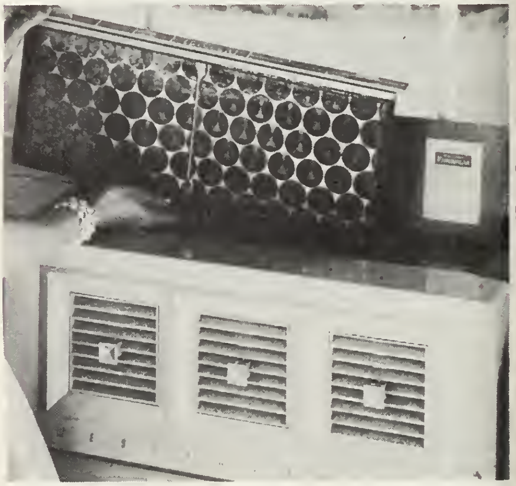
22-25. WATER FILTERS

Water is used in three ways as a filtering agent. It was first used as a spray; this method is also a humidity control. The finely divided spray will remove most of the dirt, but it cannot remove soot dirt particles (carbon), as this type of dirt cannot be wetted. Sprays are usually found in larger units.

Water is also used to wet a loosely woven cloth (cotton). This cloth is usually stretched over wire frames. The cloth is kept wet by wick action or by using slowly dripping water.

The third method is incidental to the use of a moisture condensing coil. A cooling coil operating below the dew point temperature will collect considerable water, and the air passing over this water will loose much of its dirt to this water.

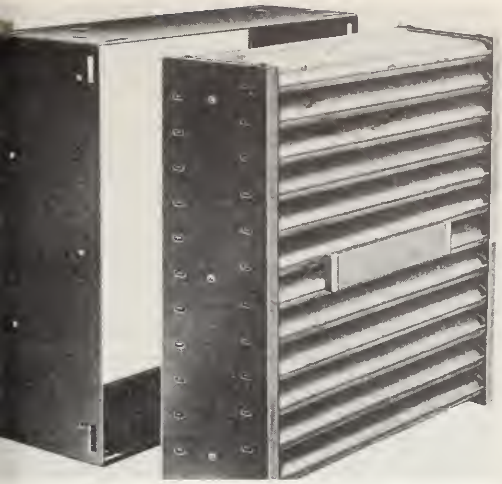
Naturally any type of water filter will require plumbing connections both for the water and to the drain.



22-25. A fiber glass filter being installed in a window unit. (Owens-Corning Fiberglass Corp.)

22-26. CARBON FILTERS

A filter that removes solid particles and one that will also remove

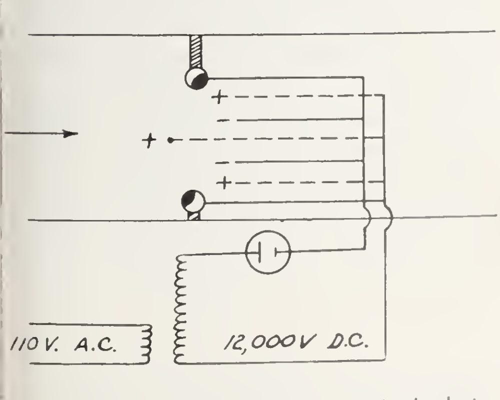


22-26. An activated carbon filter and air purifier. (W. B. Conner Engineering Corp.)

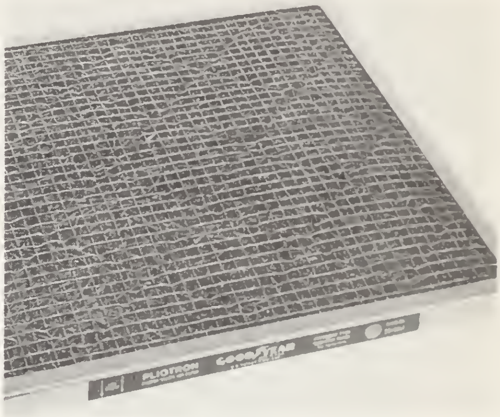
odor causing gases and bacteria is made of activated carbon surfaces. This filter has been used in air conditioners and in refrigerators with considerable success. Fig. 22-26. The carbon is in activated charcoal form and is commonly made from coconut shells. This charcoal will absorb as much as 50% of its weight in foreign gases. The filter may be renewed by baking at 1000 F. to drive out the absorbed gases.

22-27. ELECTROSTATIC CLEANING

A filter that eliminates practically all dust, is the electrostatic filter. Basically it puts a static electrical charge on all particles that pass through it. First the air passes through a highly ionized field. A wire with a very high positive voltage is suspended between grounded wires. The electrons passing through the air space will put a positive electrical charge on any particle that attempts to pass through the ionized field. This particle is then drawn to the grounded plates (negative potential). Potentials of as high as 12000 volts are used, Fig. 22-27.



22-27. Electrical circuit and air flow in a simple electrostatic type air filter.



22-28. An electrostatic filter, which is washable in water. (Goodyear Tire & Rubber Co., Inc.)

Filters which carry small static electricity charges are also available. These filters are similar in appearance to the oil film filter. However, the filter removes dirt particles by attracting them to its static electricity surfaces. The filter is cleanable. It only needs to be washed in cold water, Fig. 22-28.

22-28. OZONE

Ozone has been extensively studied as a means to improve conditioned air.

Tests have proven that ozone will improve air but its use above 0.01 to 0.05 parts per million of air may

cause an unpleasant odor and may cause breathing difficulties and even stupor.

22-29. REVIEW QUESTIONS

1. When was the first scientifically designed air conditioning system installed?
2. Who is called the "father" of modern air conditioning?
3. What four factors must be controlled in a complete air conditioning system?
4. Is air conditioning used only for human comfort?
5. Of what materials is the living portion of the atmosphere made?
6. In what form does water exist in the air?
7. What is fog?
8. What is a grain?
9. What is a micron?
10. List at least two temperatures one should know about any particular air sample?
11. Define psychrometry.
12. How does air movement affect one's comfort?
13. What is the boiling or evaporating temperature of water at 1 in. hg. pressure?
14. List two ways to remove moisture from the air.
15. What happens to the moisture absorption of air as the temperature decreases?
16. How should a psychrometer be used?
17. What values are constant along a horizontal line on the psychrometric chart?
18. Does the air contain moisture at temperatures below 32 F?
19. When air is heated, what happens to the relative humidity?
20. Under what conditions are most people comfortable in the summer?
21. List three uses for air ducts.
22. What is the purpose of a grille?
23. How large are dust particles?
24. What are fumes?
25. Describe the difference between a vapor and a gas.
26. How can oil remove impurities from air?
27. How does an ultra-violet ray help clean air?
28. Describe how a cooling coil helps clean the air.
29. What is the principal impurity removed by an activated carbon filter?
30. How is electricity used to remove dust from the air?

22-30. DISCOMFORT INDEX

A discomfort index is a numerical method used to indicate the possibility of human discomfort. This measurement is also called a Temperature-Humidity Index (THI). It is determined by adding the wb and db temperatures, multiplying by .4 and then adding 15.

Example: 90db + 80wb = 170 x .4 = 68.0 + 15 = 83

According to the U. S. Weather Bureau

Discomfort Index	% of people who will be uncomfortable
70	10
75	50
79	100

Chapter 23

AIR DISTRIBUTION INSTRUMENTS

Air conditioning mechanisms are designed to condition the air within the mechanism and then to distribute this treated air to the proper place, in the proper amounts, and with the least possible annoyance to the consumer of the conditioned air.

When a radiator system, such as a steam heating plant or a hot water plant, is used, the distribution of air is very simple. The radiators are located along the outside walls and the heated air rising from the radiator along the wall mixes with the cold air adjacent to the cold wall, and the mixture is then distributed by natural convection throughout the room.

However, the warm air furnace gave rise to more complicated problems in air distribution. The air is still circulated by natural convection, but the air passages have to be proportioned so that the longer run ducts are made larger and the larger rooms also have larger ducts. Means also had to be devised for cold air from the rooms to return to the furnace. The advancement from the simple one duct cold air return, to complicated multiple cold air returns from each conditioned room illustrates the need that one study air distribution very carefully.

23-1. USE OF AIR

In air conditioning practice, as air is passed through the mechanism it is heated or cooled, humidified or dehumidified, cleaned, and then distributed to those places where it is needed. This shows that the air conditioning unit, no matter how efficient it is, and regardless of its size, would be handicapped if the air could not be distributed efficiently. It is very important that the air distribution be accurately proportioned to the need and to the apparatus to which it is included.

23-2. WEIGHT OF AIR

Air has definite weight. Although it is invisible, its gases have a definite mass, and it therefore takes energy to move air. At 70 F., 13.34 cu. ft. of dry air weighs one pound, and if this is 50% saturated with moisture, 13.31 cu. ft. of the air and moisture mixture weighs one pound. Because air is a gas, it responds to the Boyles and Charles Laws and, therefore, as the temperature rises, it takes more cubic feet to weigh one pound. As the pressure decreases, it takes more cubic feet to weigh one pound. Fig. 23-1 illustrates the weight of air under various temperature and humidity conditions.

23-3. HEAT IN AIR

Because air is a physical substance, it has a heat carrying capacity. It can transport heat, either removing it from a space or carrying it to a space. The

Air Temp. F	Cu.ft./lb. dry air	Lb./cu.ft. dry air	Cu.ft./lb. 50% saturated	Lb./cu.ft. 50% saturated	Cu.ft./lb. 100% saturated	Lb./cu.ft. 100% saturated
0	11.58		11.585		11.59	
50	12.84		12.915		12.99	
70	13.34		13.51		13.68	
100	14.10		14.585		15.07	
120	14.60		15.55		16.50	
150	15.3		17.7			
200	16.7					

23-1. The weight of air at various temperatures and humidities.

psychrometric properties already studied show the varying heat content due to temperature changes and to humidity changes. The specific heat of dry air is .24 Btu per pound. The additional heat due to the moisture in the air varies considerably depending on the amount of saturation.

For example, at 100 F. there are 24 Btu's in one pound of dry air. There may be .04293 lbs. of moisture added to this one pound of dry air to saturate it, but the heat in this moisture is 47.40 Btu (latent heat and sensible heat) and so the total weight of 1.04293 pounds is 71.40 Btu. However, as far as distributing the air is concerned, only sensible heat need be taken into account unless vaporizing or condensing of water takes place in the ducts, or in the room being conditioned.

There are 7000 grains to a pound and, because it requires about 1000 Btu/lb. to change water to water vapor, each grain of water changed to vapor requires a latent heat of 1000/7000 or .143 Btu/grain. If condensation takes place in a cooled air duct or on the outside surface, the heat released is considerable and the temperature of the air delivered to the conditioned space can be changed drastically and may cause a failure in operation. Open pans of water in a heated room can cool the air considerably as the air absorbs the evaporating moisture, again tending to cause a failure of the machine to give good results. Only sensible heat changes should take place outside of the apparatus itself.

Use	Air Changes/Hour Heating	Cooling
Homes	3-6	6-9
Offices Stores	5-8	6-12
Public Assembly	5-10	6-12

23-2. Recommended air changes for various types of occupancies.
(American Society of Refrigerating Engineers)

23-4. BASIC VENTILATION REQUIREMENTS

As noted before, air is a mixture of gases, and normally the air contains about 21% oxygen. A human system requires that a certain oxygen content be contained in the air: (1) to maintain life and (2) to be comfortable. If a room is tightly sealed, any human in that room would slowly consume the oxygen and increase the carbon dioxide content, the water vapor content, and various small amounts of impurities. It is of utmost importance that fresh air be admitted to the room. In the past, this fresh air entered the space by infiltration from the outside due to door and window openings with their associated cracks. However, modern construction is reducing this air leakage to a minimum. It is now necessary to use air conditioning apparatus to furnish this fresh air. The units have a controlled fresh air intake, and this

fresh air is conditioned and mixed with the recirculated air before it reaches the room.

The amount of fresh air required depends on the use of the space and the amount of fresh air admitted by infiltration.

If the amount of impurities in the air, odor, smoke, bacteria etc. are the cause for requiring more fresh air, this may be reduced by using various air cleaning systems.

Ventilation is usually based on air changes per hour for the conditioned space. If the space is 1000 cu. ft. for example, three changes per hour would mean 3000 cu. ft. per hour or 50 cu. ft./min. This is the minimum for heating residences. As high as 12 changes per hour (in the above case 200 cu. ft./min.) are recommended for cooling. See Fig. 23-2.

23-5. NOISE

The air distributing system must not only handle the heat load and the fresh air required, but it must do these functions in a manner that will not be annoying to the occupants. Two causes of annoyance are objectionable drafts and noise.

The noise problem can be divided into three types:

1. Noise source
2. Noise carriers
3. Noise amplifiers or reflectors

The noise source is an audible vibration. This vibration may originate in the heating unit, in the cooling unit, in the fan mechanism, in air turbulence, in the duct panels or hangers, or in the grilles.

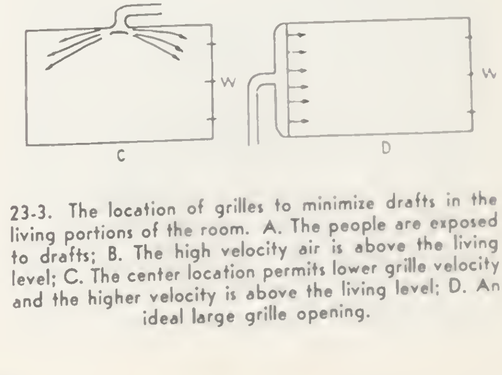
The noise carriers are rigid structures that carry the vibrations of any source to places where it may be annoying to the people in the area. Floors, ceilings, ducts, doors, pipes -- all may carry these vibrations.

Noise amplifiers or reflectors are usually hard smooth surfaces in the conditioned space. Walls, ceilings, floors, and furnishings may pick up a small vibration and reflect it in such frequency and in such a direction that all or certain parts of the space may be made uncomfortable. The problem of acoustics and the maintenance of a low decibel noise level is being constantly studied and improved.

23-6. DRAFTS

It is a relatively simple matter to provide ducts large enough and fans large enough to provide a room with the correct amount of air for conditioning. However, the problem of putting this air into the room, distributing it to all parts of the room without short circuiting the air to the air return, without objectionable drafts, and without irritating noise, is a difficult task.

When air moves at a velocity that exceeds 25 ft./min. (about 1/3 miles/hr.), most people feel an annoying draft. This means that, if the air flows faster than one mile per minute through the length of a 25 foot living



23-3. The location of grilles to minimize drafts in the living portions of the room. A. The people are exposed to drafts; B. The high velocity air is above the living level; C. The center location permits lower grille velocity and the higher velocity is above the living level; D. An ideal large grille opening.

room, an uncomfortable feeling results.

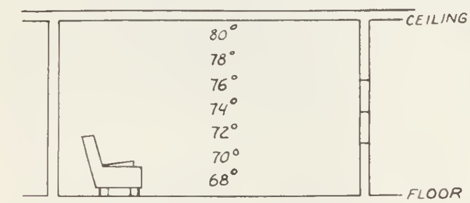
To have a grille outlet designed to throw the air into the room a distance of 8 to 13 feet, a velocity of 500 ft./min. (6 mi./hr.) is needed. Therefore, to keep that part of the space occupied by humans at a 25 ft./min. velocity, the location of the grilles or outlets must be carefully designed, Fig. 23-3.

23-7. STRATIFICATION OF AIR

Air in an occupied space must be kept moving, or stagnation or stratification results. Warm air tends to rise, cold air tends to settle, and in a room where the air is not deliberately moved the air will assume levels according to its temperature, Fig. 23-4.

It is important to locate all automatic controls at the proper level because of this stratification. Also stratification tends to make smoke haze hover in layers.

Unfortunately some grilles are so located that the air will only be moved



23-4. The various temperature levels found in a room having little or no air circulation.

in certain parts of the room and the air will become stagnant in the others. There is also the problem of the obstruction to air movement caused by the furnishings of the room. For this reason and to enable higher grille velocities, some grilles are located high in the room (6 ft. or more), and some may be located in the ceiling. These high grille locations necessitate that the grilles be attractive in appearance or concealed, Fig. 23-5.

23-8. AIR DUCTS

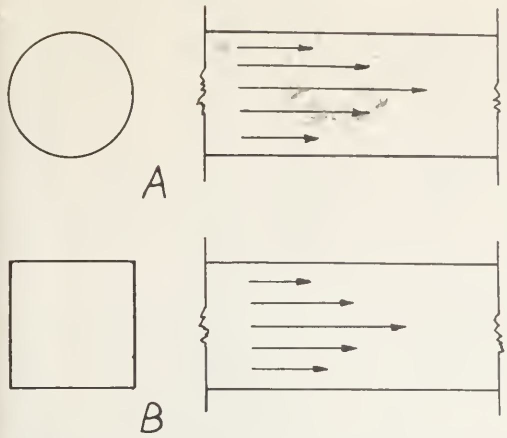
To deliver air to the conditioned space, air carriers are needed. These carriers are called ducts. These ducts are preferably made of metal or some non-combustible material.

The ducts work on the principle of air pressure difference. If a pressure difference exists, air will move from the high pressure spot to the lower pressure places. The greater this pressure difference the faster the air will flow.

23-5. A ceiling grille that diffuses the air as well as it delivers it to the room.
(Anemostat Corp. of America)

There are two popular shapes of ducts used for carrying air: (1) the round duct, (2) the square or rectangular duct. See Fig. 23-6. The round duct is the more efficient based on volume of air handled per perimeter distance (distance around). That is, less sheet metal is needed to make a large enough duct to carry the necessary air.

The square or rectangular duct has need for more metal for equal volumes. Also the square duct has four inefficient corners where the air is difficult to move and must be almost neglected when one calculates the air it can carry. The rectangular duct, however, harmonizes with building con-



23-6. Round and rectangular ducts. The arrows indicate how the air flow is slower the closer the air is to the surfaces of the duct.

struction and fits into the walls and ceilings better. It also is easier to install rectangular ducts between joists and studs.

A table has been developed showing the rectangular ducts that have equal carrying capacities to round ducts, Fig. 23-8.

A 20 inch round duct has a perimeter of: Diameter x π = circumference (perimeter)

20 x 3.1416 = 62.832 inches.

A rectangular duct of equal capacity is 14 x 23 in. It has a perimeter of

W + W + D + D = perimeter

23 + 23 + 14 + 14 = perimeter

46 + 28 = 74 inches

74 inches - 62.832 = 11.17 inches

This means 11.17 inches of metal more around, and that for each length of duct an extra square foot of metal is needed.

23-9. DUCT SIZES

To determine the size duct that should be used to carry air to a room, it is necessary to first find the volume of air that is to be delivered to the room.

This volume of air depends on the amount of heat the air must deliver to the room during the heating season or the amount of heat to be removed during the cooling season.

These calculations are not complicated in most cases, but situations using split heating systems, etc. make the problem more complicated.

The amount of air delivered to a room must always be equal to or exceed the minimum ventilation requirements.

23-10. AIR VOLUMES FOR HEATING

If the heated air is furnishing all the heat for a room, three things must be known to be able to calculate the air volume:

1. The heat load
2. The room temperature
3. The duct temperature

The heat load can be determined by using the methods described in Chapter 24. The room temperature is decided by the designer, normally it is 72 F. dbt. The duct air temperature is more difficult to decide. If a low duct temperature is used, large air volumes will be necessary to carry enough heat. If high duct temperatures are used, the furnace will have to operate with higher chimney (stack) temperatures, and the ducts themselves may have to be insulated.

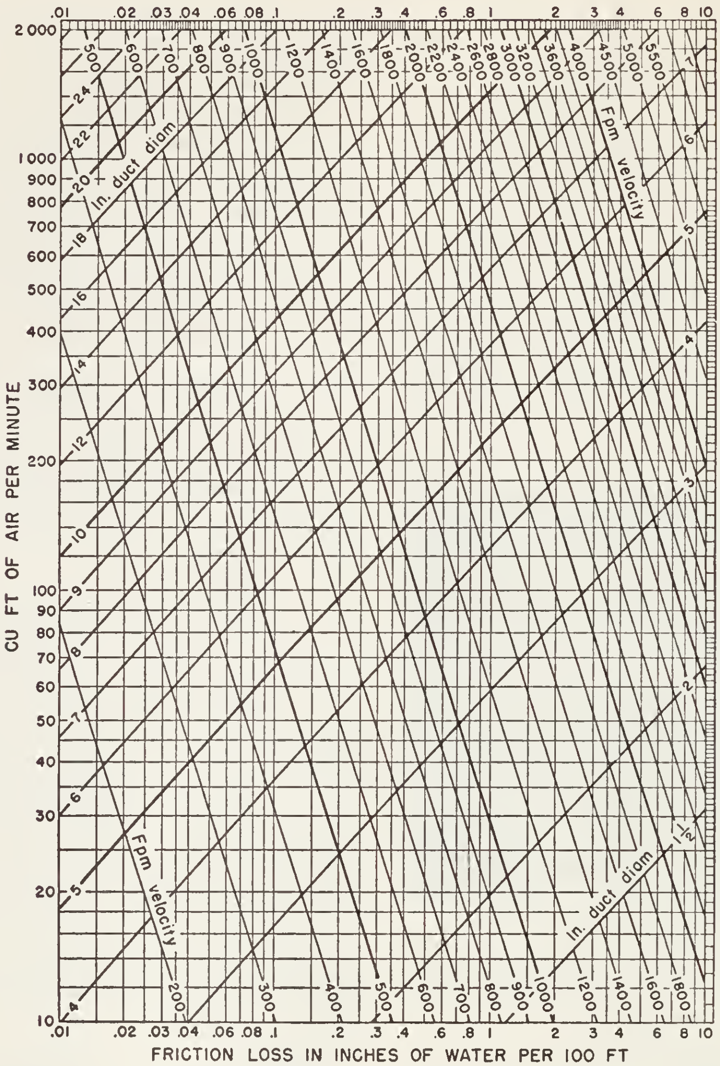
Engineers recommend that the grille temperatures be at least 125 F., and that duct temperatures be near 140 F. The lowest temperature needed to obtain these results depends on the duct lengths. Knowing that the specific heat of air is .24 Btu/lb., the weight of air needed is easily found by using the specific heat equation.

Room Heat Load = .24 x Wt. of air x the temperature difference

For example:

What is the air weight if a room has a heat load of 20,000 Btu/hr?

With a room temperature of 72 F. and a duct temperature of 140 F., the



For Volumes of 10 to 2000 cfm

(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, **round**, galvanized metal ducts having approximately 40 joints per 100 ft.) **No safety factor included.** Caution: Do not extrapolate below chart.

23-7. A friction chart for low volume air flow in ducts.
(Am. Soc. of Heating and Air Conditioning Engrs.)

temperature difference is 68 F.

$20.000 = .24 \times \text{Wt. of air} \times 68$

$$\frac{20000}{.24 \times 68} = \text{wt. of air}$$

$$\frac{20000}{16.32} = \text{wt. of air}$$

1225.5 pds = wt. of air per hour

Divide by 60 min/hour

20.435 pds = wt. of air per min.

To obtain the volume, one must first find the volume of one pound of air at the duct temperatures. This value is obtained from the psychrometric chart, Fig. 22-13.

One pound of air = 17.1 cu. ft. If the chart does not read as high as 140 F., one can calculate for this volume using Charles Law and knowing the volume at 72 F. dbt. and 50% rh (13.55 cu. ft.)

$$\frac{13.55}{\text{Vol.}} = \frac{460 + 72}{460 + 140} = \frac{532}{600}$$

$13.55 \times 600 = \text{Vol} \times 532$

$\frac{13.55 \times 600}{532} = \text{Vol}$

$\frac{8130}{532} = \text{Vol}$

$17.16 = \text{Vol}$

The volume of air/min. is 20.435 lbs./min. x 17.16 cu. ft.

Vol. = 350.7 cu. ft./min.

One must now determine the duct size. Two separate items must be considered. If the space is limited, the area of the duct is already fixed. For example, if the duct is to run between studs in a partition, the space available is 14 x 3 1/4 in. maximum (2 x 4 studding on 16 in. centers). This duct has an area of

$14 \times 3\ 1/4 = 43.5$ sq. min.

$\frac{45.5}{144} = .316$ sq. ft.

Using the above volume

The velocity in ft/min x .316 sq. ft. = 350.7 cu. ft./min.

$$\text{Velocity} = \frac{350.7}{.316} = 1110 \text{ ft/min.}$$

This velocity produces air turbulence noise and one must therefore use two ducts of 14 x 3 1/4 in. size.

The velocity will now be 555 ft./min. which should be satisfactory.

23-11. AIR CIRCULATION

Heating systems have used these systems to circulate the air.

1. Gravity
2. Intermittent forced air
3. Continuous forced air

The gravity system is decreasing in popularity. However, it has the advantage of simplicity and a steady temperature in the rooms. A Standard Code for Installation of Gravity Warm Air Heating Systems is published by the National Warm Air Heating and Air Conditioning Association.

This code recommends register or grille temperatures of 175 F. It has tables that indicate the Btu carrying capacity of five different duct combinations for either first or second floor registers.

The same association has developed a Code for mechanical warm air systems.

The continuous blower operation system is increasing in popularity. This system provides a more constant temperature in the rooms.

23-12. UNIT PRESSURE DROP SYSTEM

When air is forced through a duct, it follows the path of least resistance. Many air conditioning duct systems have several openings for the air to escape from the duct. A duct with a low air flow resistance will allow most of the air to flow through it, and the other ducts will not obtain their correct amount of air. In the past many duct installations were made that fed too much air to some rooms and did not heat other rooms sufficiently.

The unit pressure drop calculating system, uses the same pressure drop for each length of duct throughout the system.

For example, if the total heat load is 80,000 Btu/hr, and there are five rooms with heat loads as follows:

1. Living Room = 25,000 Btu/hr.
2. Dining Room = 15,000 Btu/hr.
3. Kitchen = 5,000 Btu/hr.
4. Bathroom = 8,000 Btu/hr.
5. Bedroom No. 1 = 15,000 Btu/hr.
6. Bedroom No. 2 = 12,000 Btu/hr.

Based on the previous problems

$\frac{\text{Btu/hr.}}{\text{cfm}} = \frac{20,000}{350.7} = 5.7$ Btu/cu. ft. of air,

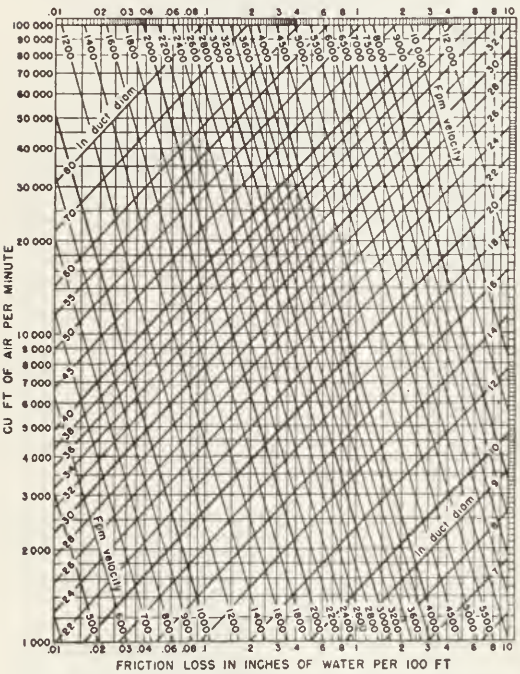
the air volumes required per min. for each room are:

1. Living Room 438.6 cu. ft./min.
2. Dining Room 263.2 cu. ft./min.

3. Kitchen 87.73 cu. ft./min.
4. Bathroom 140.3 cu. ft./min.
5. Bedroom No. 1 263.2 cu. ft./min.
6. Bedroom No. 2 210.5 cu. ft./min.

The total air volume is 1403.53 cu. ft./min.

To determine the duct sizes to handle the air volumes specified above, data must be obtained about air flow, Figs. 23-7 and 23-8. This chart has four variables (1) Friction loss in inches of water on the horizontal scale



23-8. A friction chart for high volume air flow in ducts. (Am. Soc. of Heating and Air Conditioning Engrs.)

(2) Cu. ft. of air/min on the vertical scale (3) Velocity on a scale that slants down to the right and, (4) a round duct diameter scale that slants down to the left.

In the problem above the main duct must handle 1403.53 cu. ft./min. To keep the velocity to a low noise level, a friction loss of .04 in H_2O per 100 ft. should be used. On the chart, these two values meet and show that the velocity will be 730 ft./min., and the

Dimensions in Inches

Side Rectangular Duct	6	7	8	9	10	11	12	13	14	15	16	17	18	19
6	6.6													
7	7.1	7.7												
8	7.5	8.2	8.8											
9	8.0	8.6	9.3	9.9										
10	8.4	9.1	9.8	10.4	10.9									
11	8.8	9.5	10.2	10.8	11.4	12.0								
12	9.1	9.9	10.7	11.3	11.9	12.5	13.1							
13	9.5	10.3	11.1	11.8	12.4	13.0	13.6	14.2						
14	9.8	10.7	11.5	12.2	12.9	13.5	14.2	14.7	15.3					
15	10.1	11.0	11.8	12.6	13.3	14.0	14.6	15.3	15.8	16.4				
16	10.4	11.4	12.2	13.0	13.7	14.4	15.1	15.7	16.3	16.9	17.5			
17	10.7	11.7	12.5	13.4	14.1	14.9	15.5	16.1	16.8	17.4	18.0	18.6		
18	11.0	11.9	12.9	13.7	14.5	15.3	16.0	16.6	17.3	17.9	18.5	19.1	19.7	
19	11.2	12.2	13.2	14.1	14.9	15.6	16.4	17.1	17.8	18.4	19.0	19.6	20.2	20.8
20	11.5	12.5	13.5	14.4	15.2	15.9	16.8	17.5	18.2	18.8	19.5	20.1	20.7	21.3
22	12.0	13.1	14.1	15.0	15.9	16.7	17.6	18.3	19.1	19.7	20.4	21.0	21.7	22.3
24	12.4	13.6	14.6	15.6	16.6	17.5	18.3	19.1	19.8	20.6	21.3	21.9	22.6	23.2
26	12.8	14.1	15.2	16.2	17.2	18.1	19.0	19.8	20.6	21.4	22.1	22.8	23.5	24.1
28	13.2	14.5	15.6	16.7	17.7	18.7	19.6	20.5	21.3	22.1	22.9	23.6	24.4	25.0
30	13.6	14.9	16.1	17.2	18.3	19.3	20.2	21.1	22.0	22.9	23.7	24.4	25.2	25.9
32	14.0	15.3	16.5	17.7	18.8	19.8	20.8	21.8	22.7	23.6	24.4	25.2	26.0	26.7
34	14.4	15.7	17.0	18.2	19.3	20.4	21.4	22.4	23.3	24.2	25.1	25.9	26.7	27.5
36	14.7	16.1	17.4	18.6	19.8	20.9	21.9	23.0	23.9	24.8	25.8	26.6	27.4	28.3
38	15.0	16.4	17.8	19.0	20.3	21.4	22.5	23.5	24.5	25.4	26.4	27.3	28.1	29.0
40	15.3	16.8	18.2	19.4	20.7	21.9	23.0	24.0	25.1	26.0	27.0	27.9	28.8	29.7
42	15.6	17.1	18.5	19.8	21.1	22.3	23.4	24.5	25.6	26.6	27.6	28.5	29.4	30.4
44	15.9	17.5	18.9	20.2	21.5	22.7	23.9	25.0	26.1	27.2	28.2	29.1	30.0	31.0
46	16.2	17.8	19.2	20.6	21.9	23.2	24.3	25.5	26.7	27.7	28.7	29.7	30.6	31.6
48	16.5	18.1	19.6	20.9	22.3	23.6	24.8	26.0	27.2	28.2	29.2	30.2	31.2	32.3
50	16.8	18.4	19.9	21.3	22.7	24.0	25.2	26.4	27.6	28.7	29.8	30.8	31.8	32.8
52	17.0	18.7	20.2	21.6	23.1	24.4	25.6	26.8	28.1	29.2	30.3	31.4	32.4	33.4
54	17.3	19.0	20.5	22.0	23.4	24.8	26.1	27.3	28.5	29.7	30.8	31.9	32.9	33.9
56	17.6	19.3	20.9	22.4	23.8	25.2	26.5	27.7	28.9	30.1	31.2	32.4	33.4	34.5
58	17.8	19.5	21.1	22.7	24.2	25.5	26.9	28.2	29.3	30.5	31.7	32.9	33.9	35.0
60	18.1	19.8	21.4	23.0	24.5	25.8	27.3	28.7	29.8	31.0	32.2	33.4	34.5	35.5
62	18.3	20.1	21.7	23.3	24.8	26.2	27.6	29.0	30.2	31.4	32.6	33.8	35.0	36.0
64	18.6	20.3	22.0	23.6	25.2	26.5	27.9	29.3	30.6	31.8	33.1	34.2	35.6	36.5
66	18.8	20.6	22.3	23.9	25.5	26.9	28.3	29.7	31.0	32.2	33.5	34.7	35.9	37.0
68	19.0	20.8	22.5	24.2	25.8	27.3	28.7	30.1	31.4	32.6	33.9	35.1	36.3	37.5
70	19.2	21.	22.8	24.5	26.1	27.6	29.1	30.4	31.8	33.1	34.3	35.6	36.8	37.9

23-9. The width of duct necessary for a rectangular duct to equal the carrying capacity of a round duct. (Am. Soc. of Heating and Air Conditioning Engrs.)

round duct will be 18 1/2 in. in dia.

Using this same friction loss for the branch ducts, one may obtain the following round duct sizes.

1. Living Room = 550 ft./min. and 12.1 in. diameter
2. Dining Room = 480 ft./min. and 9.8 in. diameter
3. Kitchen = 370 ft./min. and 6.9 in. diameter
4. Bathroom = 410 ft./min. and 7.9 in. diameter
5. Bedroom No. 1 = 480 ft./min. and 9.8 in. diameter
6. Bedroom No. 2 = 460 ft./min. and 9.2 in. diameter

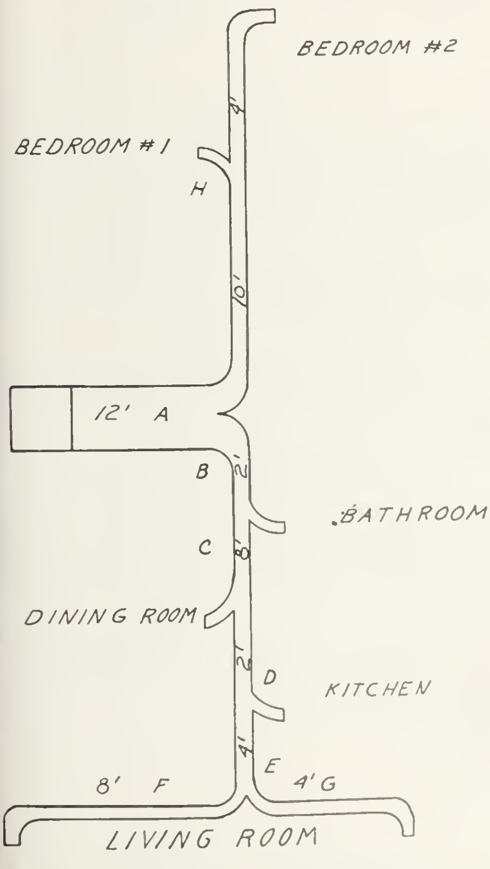
These velocities are reasonably low, and the system would work. However, a more accurate system is the total pressure drop system.

The round duct diameters are changed to rectangular duct sizes by the table shown in Fig. 23-9.

When changing round duct sizes to rectangular duct sizes, it is important to remember that partition ducts cannot exceed $3\frac{1}{4}$ in. in depth and 14 inches in width. Also, all the ducts in the basement should have the same depth for appearance purposes and to enable easy concealment of the ducts in cases where the basement is used as a recreation space or living quarters. It is recommended that the basement ducts not exceed 8 in. in depth.

23-13. THE TOTAL PRESSURE DROP SYSTEM

The unit pressure drop system is accurate enough for simple duct installations that do not have long duct runs or great differences in duct sizes.



23-10. A typical duct installation.

A more accurate system is based on having the same total pressure drop from the fan to each outlet. Fig. 23-10 shows the duct system used with the rooms as calculated in Paragraph 23-12. To keep the various ducts identified, it is good practice to letter each different size duct.

In the illustration, the following air volumes must be carried.

Duct	Air Volumes
A	1404
B	930
C	790
D	526
E	439
F	220
G	220
H	474
I	211

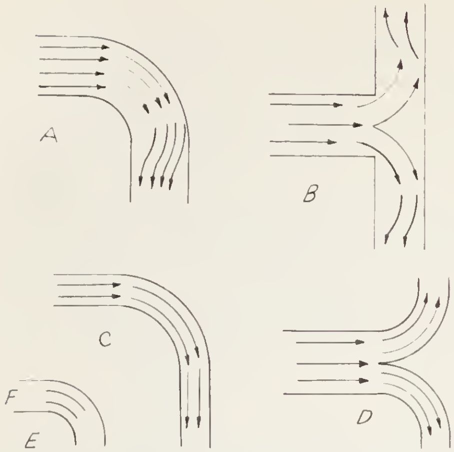
To be sure that the correct air volume leaves each outlet, it is necessary to have each outlet produce the correct equal amount of air resistance.

The method followed is to determine the longest and most complicated duct. This combination is obviously A, B, C, D, E, and F.

If one were to assume a total pressure drop of .04 inches of water, this total means that the pressure drop to each room outlet must be .04 inches. For example, the opening to the bathroom is the shortest overall distance. It must have the same total pressure drop as the longest run through F.

An important part of this duct design is that the bends and elbows must be considered when determining pressure drop. Generally speaking, the pressure drop of one elbow is equal to 10 diameters of the duct. Assuming there is one large bend above the furnace and that the grilles are located at the 7 ft. level in the room, the total length of duct A B C D E F is approximately:

Elbow (18x10)	15 ft.
A	12 ft.



23-11. Air flow in duct bends and elbows.

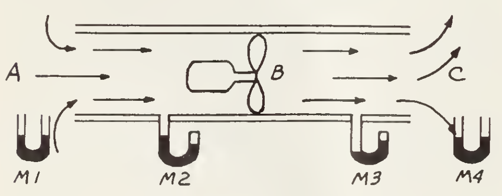
Elbow (16x10)	13 ft.
B	2
C	8
D	2
E	4
Elbow ($9\frac{1}{2}$x10)	8
F	8
Elbow	8
Vertical Rise	7
Elbow	8
Total	95 ft.

The total length (equivalent) is 95 feet. Because the .04 in. pressure drop was for 100 ft., the new pressure drop for each actual foot of duct is:

$\frac{100}{95} \times .04 = \frac{20}{19} \times .04 = \frac{.8}{19} = .042$ in water/100 ft.

However, more important than this factor is the pressure drop in each section of the longest duct.

Elbow (18in. x 10)	$= .04 \times \frac{15}{95} = .0063$
A	$= .04 \times \frac{12}{95} = .0050$
Elbow (16 in. x 10)	$= .04 \times \frac{13}{95} = .0055$
B	$= .04 \times \frac{2}{95} = .0008$
C	$= .04 \times \frac{8}{95} = .0034$
D	$= .04 \times \frac{2}{95} = .0008$
E	$= .04 \times \frac{4}{95} = .0016$
Elbow ($9\frac{1}{2}$ x 10)	$= .04 \times \frac{8}{95} = .0034$
F	$= .04 \times \frac{8}{95} = .0034$
Elbow	$= .04 \times \frac{8}{95} = .0034$
Vertical Rise	$= .04 \times \frac{7}{95} = .0029$
Elbow	$= .04 \times \frac{8}{95} = .0034$
Total =	.0399 = .04 in water pressure drop



23-12. Pressure conditions in a simple duct and fan installation. A. Intake; B. Fan and motor; C. Exhaust; M-1. Atmospheric pressure; M-2. Negative pressure; M-3. Positive pressure; M-4. Atmospheric pressure.

Knowing the pressure drop in each part of the longest duct, one can now determine the pressure loss up to each branch duct, and then from this value and the length of the branch duct determine the pressure loss 100 ft. for each branch duct.

For example. The kitchen duct.

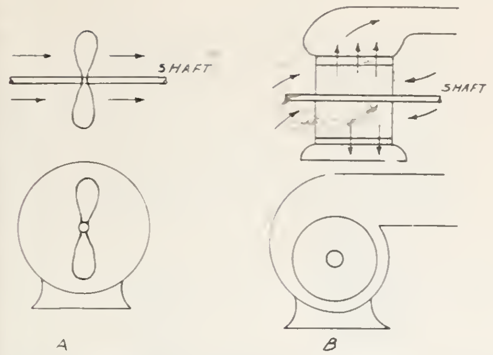
The pressure loss up to the kitchen branch duct is .0063 + .0050 + .0055 + .0008 + .0034 + .0008 = .0218

If the total pressure drop to the outlet at the kitchen must equal .04 inches water, therefore .0400 - .0218 = .0182 as the pressure drop in the kitchen branch.

The kitchen branch has an equivalent length of

Elbow (6.9'' x 10)	= 6 ft.
Riser	= 7 ft.
Elbow (6.9'' x 10)	= 6 ft.
Total	19 ft.

If the pressure drop in 19 ft. is .0182, the pressure drop per 100 ft. = $.0182 \times \frac{100}{19} = \frac{1.82}{19} = .096$ in. water/100



23-13. Principal types of fans. A. Axial flow; B. Radial flow.

ft. From the graph, using 87.73 cu. ft./min. volume and the resistance of .096 in., the following data is obtained:
Size = 5.8 in. dia.
Velocity = 530 cu. ft./min.

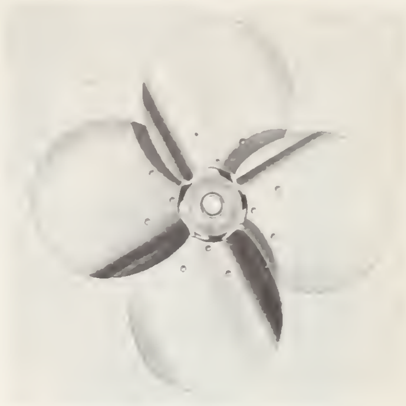
Notice how these values differ from the unit pressure drop values.

23-14. ELBOWS

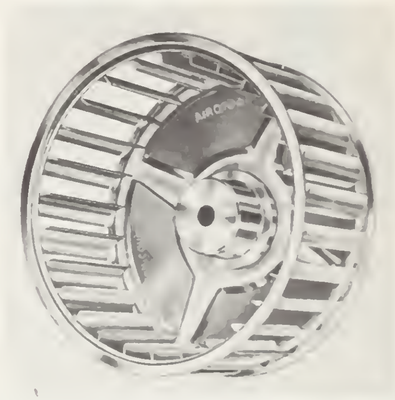
Air has inertia. That is, air has weight and it obeys the Newton laws of motion. In addition, air is compressible and, because of these laws, air in motion has the following characteristics: It takes energy to make air flow change direction. The air wants to flow in a straight line, and it therefore crowds against the outside on turns. Fig. 23-11 (A) represents a typical elbow. It has a very short radius of bend. The pressure drop through the elbow is about 10 times an equal length of duct. (C) is a much better air flow duct, but its cost and room for installation make it impractical for many installations. (B) is a turbulent air duct design, and (D) is the type of duct with a much better air flow design. (E) is a duct elbow with vanes located at the bend. These vanes (F) considerably reduce the pressure drop.

23-15. FANS

Air movement is usually produced by some type of fan. These fans are usually located at the inlet of the air conditioner. Air movement can be produced by either creating an above atmosphere pressure (positive pressure) or by creating a below atmosphere pressure (negative pressure). Actually, all fans produce both conditions; the air inlet to a fan is below atmosphere condition, and the above atmosphere condition is in the exhaust of the fan. See Fig. 23-12. The air feed into a fan is called induced draft and the air exhaust from a fan is called forced draft.



23-14. Blade for axial flow fan.
(Torrington Mfg. Co.)

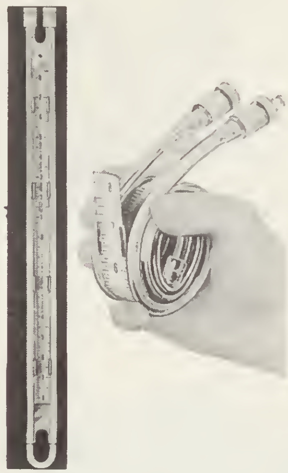


23-15. Rotor for radial flow fan.
(Torrington Mfg. Co.)

There are several types of fans, but the two most popular are:

1. Axial flow fan (propeller)
2. Radial flow fan (squirrel cage)

The basic construction shows that the type of fan is named after the direction the air flows. If along the axle, it is called axial flow. If perpendicular to the axle (radius), it is called radial flow, Fig. 23-13. The blade or rotor elements are shown in Fig. 23-14 and Fig. 23-15.



23-16. A manometer used for measuring air flow in ducts and also for checking drafts. A. Open ready for use; B. The flexible tube permits easy storing. (F. W. Dwyer Mfg. Co.)

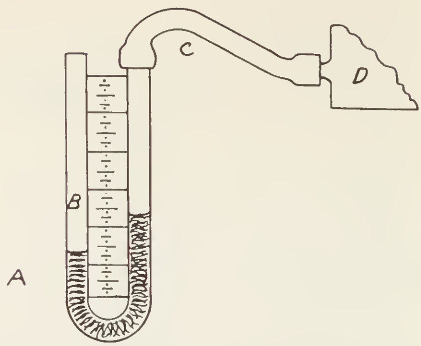
23-16. INSTRUMENTS

Because air is invisible, instruments are especially important to measure air flow and pressure conditions. Thermometers and pressure gauges are already known to the reader. Some different instruments especially useful for air flow study are:

1. Manometer
2. Barometer
3. Pitot Tube
4. Anemometer
5. Smoke as a velocity indicator
6. Kata Thermometer
7. Hot Wire Anemometer

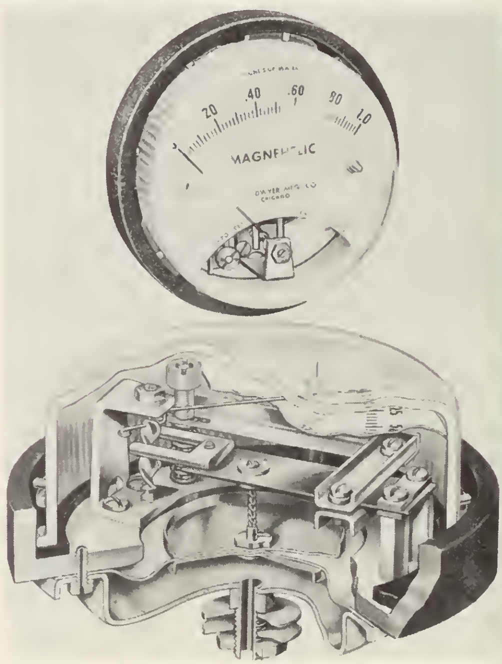
23-17. MANOMETERS

The manometer is a U-shaped tube, filled with a liquid, Fig. 23-16. If there



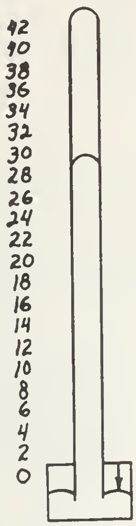
23-17. A simple manometer in operation. A. Glass tube; B. Scale; C. Rubber connecting tube; D. Pressure being measured. The pressure is indicated by the difference in level of the liquid in the two sides of the manometer and is usually measured in inches.

is a pressure difference on the two openings, the column of liquid will move until the liquid level in the low pressure side will be high enough so that its weight and the low pressure will equal the higher pressure in the other tube. See Fig. 23-17. The fluid used in



23-18. A dial type manometer. Note that the calibration is in inches of water. A. Indicates the dial and the zero adjustment. B. Shows the operating mechanism. (F. W. Dwyer Mfg. Co.)

the manometer may be either mercury or water. Mercury is used for large pressure differences and water for low pressure differences. Duct pressures usually call for water manometers. Scale B is usually movable to make it easier to adjust for the neutral point.



23-19. A simple mercury barometer.

Sudden pressure changes must be avoided, or the liquid may be forced out of the manometer.

Manometer scales are based on the following data:

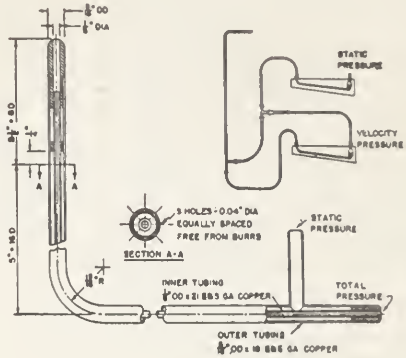
14.7 psi. = 29.9 in Hg = 34 ft. water
1 in. hg. = .492 psi
1 psi. = 2.034 in. hg.
1 psi. = 2.31 ft. water
1 ft. water = .432 psi
1 in. water = .036 psi

Dial type manometers are also available. They are more portable and are popular, Fig. 23-18.

23-18. BAROMETER

The barometer is a special form of a manometer. It is sealed at one end and uses mercury as the liquid. Because the pressure height is independent of the diameter, a single tube can be used, Fig. 23-19.

This instrument is used to determine the pressure of the atmosphere at any particular place or time.

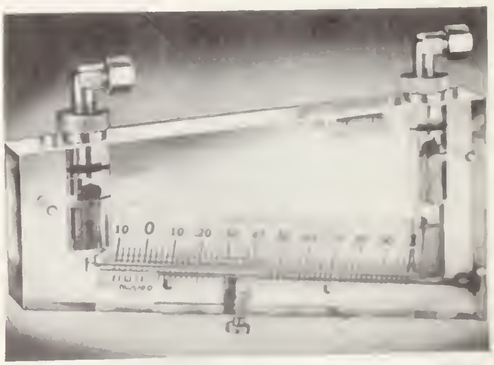


23-20. A pitot tube.
(Am. Soc. of Heating and Air Conditioning Engrs.)

23-19. PITOT TUBES

It is essential that air velocities be measured accurately in air conditioning. One must be able to measure duct velocities to determine the air volume and also, to see if the system is operating close to its design conditions.

One of the best ways to determine air velocities is to use a pitot tube, Fig. 23-20. Air contacting the nose of



23-21. An inclined gage for use with pitot tube. This gauge may also be used for measuring filter pressure drops. The unit must be carefully leveled (note the spirit level). The liquid level is easily adjusted to the zero reading.
(F. W. Dwyer Mfg. Co.)

the pitot tube creates a total pressure, and the outer tube with the holes on the side measures the static pressure. When these two pressures are connected to the end of a manometer, the difference in the pressures is the velocity pressure. An inclined manometer is used with the pitot tube to measure the velocity pressure, Fig. 23-21.

This pressure difference is measured in inches of water. Using the formula

Velocity = 4050 square root of Velocity Pressure in inches of water.

If the velocity pressure is 1 inch of water, the velocity will be:

Velocity = 4050 square root of 1 in.
Velocity = 4050 x 1
Velocity = 4050 ft./min.

Volume Cu.ft./lb.*	Velocity Constant
11.5	3720
12.1	3818
13.2	3980
**13.4	4010
14.1	4118
15.1	4260
16.2	4410
17.1	4530

*Values for any conditions may be read from the psychrometric chart.

**Standard

23-22. The change in velocity correction factor with a change in air density (effect of temperature and altitude).

If the velocity pressure is .25 inches of water:

Velocity = 4050 square root of .25
Velocity = 4050 x .05
Velocity = 202.50 ft./min.

The constant 4050 is for approximately 80 F. at a 500 ft. altitude. Other values are shown in Fig. 23-22. It is very essential that the manometer be mounted level to obtain accurate readings.

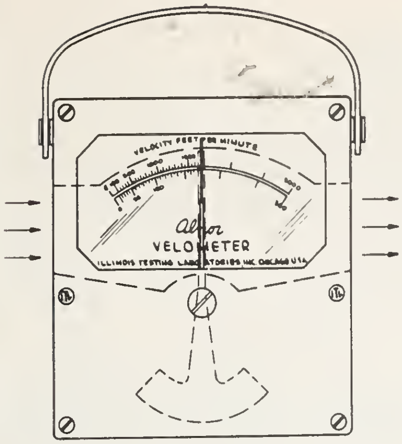
23-20. VELOCIMETERS

To avoid the arithmetic necessary with pitot tubes and to obtain quicker results, velocity measuring instruments have been developed that indicate the velocity directly. Some of the instruments are based on the cooling effect of the air flow on electrical resistance, Fig. 23-23. Some impinge the air on a small vane that tilts at different angles as the air pressure increases. Such instruments are being used extensively, Fig. 23-24.

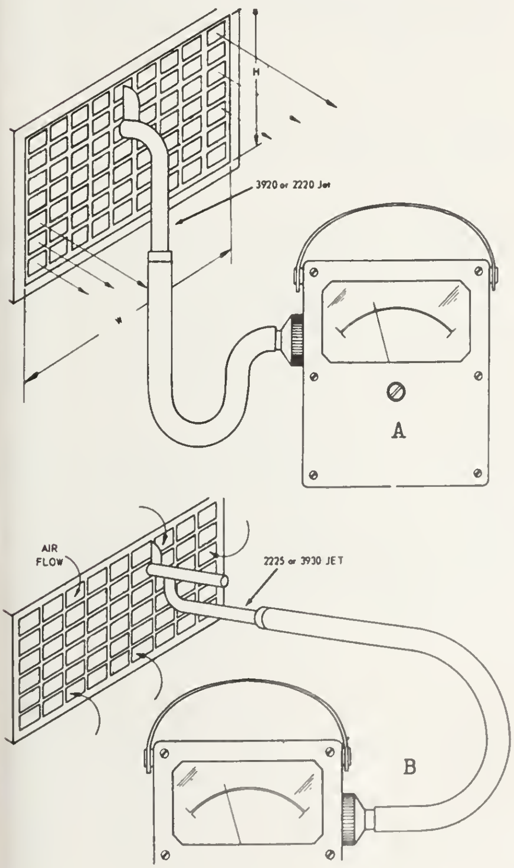
The instrument is put directly in the air stream with the left side facing the air flow. The instrument shown has two velocity scales 0-400 and 0-1600 feet per minute. The dotted lines show the air flow through the instrument proper. This instrument can be used to measure air velocities in a great variety of situations.

For velocity readings where it is inadvisable to put the instrument in the air stream or if the instrument cannot be placed in the air stream, special jets are available to get the readings. Such an arrangement is shown in Fig. 23-25.

23-23. A direct reading air velocity indicating instrument.
(Anemostat Corp. of America)



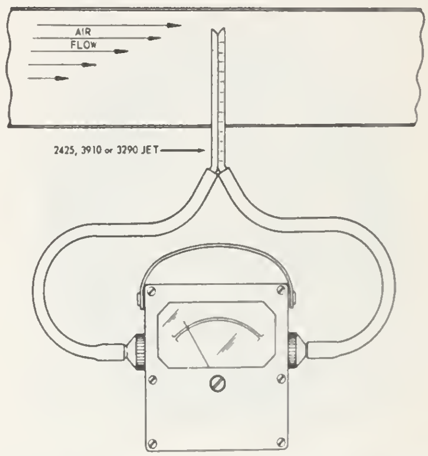
23-24. A direct reading air velocity meter. Note the air flow through the instrument from left to right. (Illinois Testing Laboratories, Inc.)



23-25. Measuring the velocities at a grille. An average of several readings over the grille face should be taken. A. Indicates the instruments used at a discharge grille; B. Indicates the suction opening application. (Illinois Testing Laboratories, Inc.)

The instrument can be used to measure air velocities out of a grille. Note that a special jet is attached to the air inlet of the instrument by means of a flexible tube. The air velocities into a cold air return are measured as shown. The jet is connected to the air outlet connection of Velocimeter in this case.

A very important use of the instrument is shown in Fig. 23-26. This jet can be used to measure velocities in



23-26. The direct reading air flow meter being used to determine the air velocity inside a duct. (Illinois Testing Laboratories, Inc.)

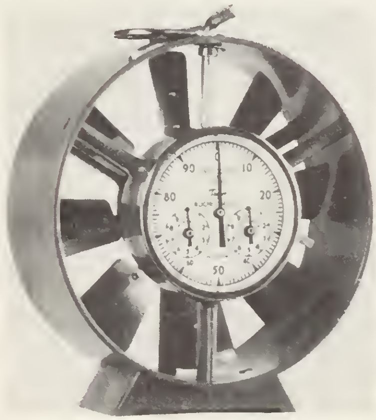
the main ducts and branch ducts. An instrument of this type is very necessary to balance air distribution systems.

The readings are very accurate. However, for extreme temperatures, the correct fpm $= \frac{460\ F. + T}{460\ F + 68} \times$ instrument-reading.

23-21. ANEMOMETERS

If a small propeller is put in an air stream it will revolve as the air flows past the blades. Correctly designed, the propeller will be practically frictionless and will measure the feet of air flowing past the blades. If the pro-

peller is connected to a dial calibrated in feet, it will indicate the feet of flow. These devices have a start lever and also a return to zero lever. To use the instrument, carefully place it in the air stream, allow it to reach a constant speed, then trip the registering mechanism. At the same time start a stop watch. Allow the unit to operate for 1 minute, then trip the stop level and stop the watch. Record the reading and the time. From this data the velocity



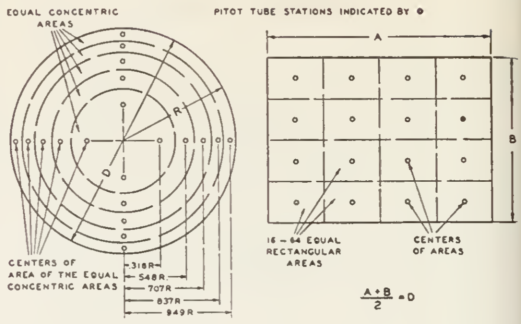
23-27. An anemometer used for measuring air flow. (Taylor Instrument Companies)

of the air in feet per minute may be readily computed. See Fig. 23-27.

If the reading is 236 for $\frac{1}{2}$ minute, the velocity will be 452 ft./min.

The pitot tube, the direct reading velocimeters, and the anemometers are not accurate at low air velocities.

To obtain correct velocity readings in a duct, several readings in various parts of the duct should be taken and the readings averaged. These readings must be accurately located, or a false value will be obtained. See Fig. 23-28. The rectangular duct is divided into equal areas, and the pitot tube is put in the center of each small area. The sixteen velocities are averaged to obtain the overall average velocity. The round duct is more difficult to meas-



23-28. Locations for velocity readings in a duct. The average of the readings will produce the average duct velocity. 0 indicates points of pitot readings. (Am. Soc. of Heating and Air Conditioning Engrs.)

ure, because it must be divided into equal circular areas. The location of each of the structure points is as recommended by the Society of Heating and Air Conditioning Engineers.

23-22. DRAFT INDICATORS

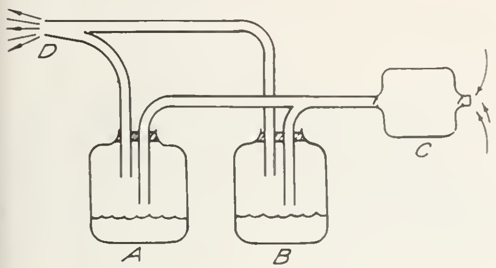
Drafts of 15 to 25 ft./min. are allowable. If the air movement is less than this, air stagnation results. If it is more than this, the persons exposed to the draft are uncomfortable.

To determine the amount of the draft and the direction, the most successful method has been to use smoke (visible vapor). Smoke generators release small puffs of smoke into the space being tested, and the distance they move in $\frac{1}{2}$ or 1 minute, is observed. Several readings must be taken and averaged to obtain a degree of accuracy.

One type of smoke generator is shown in Fig. 23-29. Each of the two bottles contains a liquid. The aspirator forces the vapors from the two bottles to mix at the nozzle. The mixing of the two gases forms a white smoke that has a density not much greater than the density of air. The liquids used are hydrochloric acid and aqua ammonia. The smoke formed is ammonium chloride.

23-23. TEMPERATURE

In many air conditioning installations, it is necessary to know the temperatures of the heat exchange surfaces, the ducts, etc. Almost all temperature indicating instruments are used for these purposes. A quick reading instrument that is easily used is shown in Fig. 23-30. This instrument has a scale from 0 to 600 F. and it operates on the thermocouple principle. Other temperature scales are also available. To use the thermometer place the end of the adjustable probe against the surface where the temperature is to be measured.



23-29. A smoke generator. A. Hydrochloric acid container; B. Aqueous ammonia; C. Rubber aspirator bulb.

23-30. A temperature measuring instrument for obtaining air and surface temperatures. (Illinois Testing Laboratories, Inc.)

23-24. REVIEW QUESTIONS

1. Does air have weight?
2. What is the specific heat of air?
3. What two air conditioning functions can air be used for?
4. How can air produce noise?
5. How fast must air be moved to produce a noticeable draft?
6. What cross section duct is the most efficient?
7. Name the two popular types of air circulating fans.
8. What produces air flow?
9. Why do elbows offer a great air flow resistance?
10. How can air flow in an elbow be improved?
11. Why must a multiple outlet air duct be carefully proportioned?
12. Why is water used as a pressure indicating liquid in manometers?
13. What is a differential manometer?
14. How does one find velocity pressure?
15. Why must one take very careful readings when measuring duct velocities?
16. What is air turbulence?
17. What is air stratification?
18. Of what material are ducts made?
19. What is the basis for the total pressure drop system?
20. List several ways to reduce noise in air ducts.

Chapter 24

HEAT LOADS

24-1. HEAT GAIN

It is important that the proper size air conditioning machine be used for the job it has to do. Fundamentally the air conditioning unit is a heat machine. For heating, it must put enough heat into a space to make up for the heat losses (heating); for cooling, it must remove as much heat as the space accumulates (cooling).

Whenever a temperature difference exists, heat energy will flow from the higher temperature to the lower temperature level. It is necessary to retard this heat flow as much as possible, because what heat is moved must be replaced in the case of heating, or the heat must be removed in the case of cooling.

The most common method is to determine the maximum amount of heat involved for the period of one hour.

24-2. TYPES OF HEAT LOADS

Heat loads consist partly of heat that is transmitted through the walls, ceilings, and floors (conduction).

1. From the outside to indoors (heating).
2. From the inside to outdoors (cooling).

The heat load also involves the heat necessary to control the moisture content in the air.

1. Adding moisture (humidifying requires additional heat)
2. Removing moisture (dehumidifying requires removal of heat)

The heat load consists of conditioning the air that enters the building by leakage and for ventilation. The sun produces heat in buildings directly through the windows, and by heating the surfaces it shines on (a cooling load). Any energy device in the building produces heat. Such items as light fixtures, electric motors, electric stoves or gas stoves; all produce heat. People, too, release a considerable amount of heat.

In all cases the heat load can be described as either sensible heat load or latent heat load (moisture).

24-3. HEATING LOADS

Heat loads for heating consist of all those means by which heat will be lost from a building or to the warming of cold substances that are brought in to the building.

The two main heat losses are:

1. Heat lost by conduction through structure walls, ceilings, and floors.
2. Heat lost by the air that leaks out of the building and that which leaks into the building (exfiltration and infiltration).

Normally all other heat losses are ignored, because they are relatively too small to affect the size of the unit to be installed.

Constants For Heat Transmission

Expressed in Btu per hour per square foot per degree temperature difference, based on 15 mph wind velocity

MASONRY CONSTRUCTION

GENERAL WALL CLASSIFICATION	MASONRY THICKNESS				
	6"	8"	10"	12"	16"
BRICK—Plain		.50		.36	
Plaster (½") Applied Directly to Brick		.46		.34	
¾" Plaster on Metal Lath		.32		.25	
½" Plaster on ½" Rigid Insulation		.22		.19	
½" Plaster on 1" Rigid Insulation		.16		.14	
CONCRETE—Plain	.79		.62		.48
½" Plaster Applied Directly to Concrete	.70		.57		.44
¾" Plaster on Metal Lath	.42		.37		.31
½" Plaster on ½" Rigid Insulation	.26		.24		.21
½" Plaster on 1" Rigid Insulation	.19		.18		.16
½" Plaster, Lath, 2" Space with Rock Wool Fill	.13		.13		.12
HOLLOW TILE—Plain		.40	.39		.25
½" Plaster Applied to One Side		.38	.37		.24
¾ Plaster on Metal Lath		.28	.27		.22
4" Brick Veneer, Hollow Tile, Metal Lath and Plaster (Tile thickness given)	.25	.25	.24	.21	
4" Brick Veneer, Hollow Tile, 2" Rock Wool Fill, Lath and Plaster (Tile thickness given)	.11	.11	.11	.10	

FRAME CONSTRUCTION

Wood Siding on 1" Wood Sheathing, Studs, Wood Lath and Plaster	.25
Wood Siding, Sheathing, Studs, ½" Rigid Insulation and Plaster	.19
Wood Siding, Sheathing, Studs, ½" Flexible Insulation, Lath and Plaster	.15
Wood Siding, Sheathing, Studs, Rock Wool Fill, Lath and Plaster	.072
Note: Frame Walls with Shingle Exterior Finish same as Walls with Wood Siding.	
Stucco, Wood Siding, Studs, Wood Lath and Plaster	.30
Stucco on 25/32" Rigid Insulation, Studs, Wood Lath and Plaster	.27
Stucco on 25/32" Rigid Insulation, Studs, ½" Rigid Insulation and Plaster	.20
Stucco on ½" Rigid Insulation, Studs, Rock Wool Fill, Lath and Plaster	.074

CONCRETE FLOORS AND CEILINGS

Note: See discussion of attic and roof temperatures where sun exposure is involved on page 10.

4" Thick Concrete, No Finish	.65
6" Thick Concrete, No Finish	.59
4" Concrete, Suspended Plaster Ceiling	.37
6" Concrete, Suspended Plaster Ceiling	.35
4" Concrete, Metal Lath and Plaster Ceiling, Hardwood Floor on Pine Sub-flooring	.23
6" Thick Concrete, Metal Lath and Plaster Ceiling, Hardwood Floor on Pine Sub-flooring	.21
4" Concrete, Hardwood and Pine Floor, No Ceiling	.31
6" Concrete, Hardwood and Pine Floor, No Ceiling	.30

PITCHED ROOFS

Wood Shingles on Wood Strips	.46
Asbestos Shingles on Wood Sheathing	.56
Tile or Slate Roofing on Wood Sheathing	.56
Wood Shingles, 1" Flexible Insulation between Rafters	.13
Asbestos or Slate Shingles, 1" Flexible Insulation.	.13

WINDOWS AND SKYLIGHTS

Single glass	1.13
Double glass, intermediate air space	.45
Hollow glass tile wall, 6" x 6" x 2" blocks	.60

BRICK VENEER ON FRAME CONSTRUCTION

Brick Veneer, 1" Wood Siding, Studs, Lath and Plaster	.27
Brick Veneer, 25/32" Rigid Insulation, Studs, Lath and Plaster	.25
Brick Veneer, 1" Wood Siding, Studs, ½" Flexible Insulation, Lath and Plaster	.16
Brick Veneer, 1" Wood Siding, Studs, Rock Wool Fill, Lath and Plaster	.071

INTERIOR WALLS

Note: In general for Cooling Computations, base the calculations for Heat Gain from adjoining non-conditioned rooms on a differential equal to ½ the differential to outside.

Wood Lath and Plaster on Studding (Both sides)	.34
Metal Lath and Plaster on Studding (Both sides)	.39
½" Rigid Insulation and Plaster (Both sides)	.18
4" Hollow Clay Tile	.45
4" Gypsum Block	.30
4" Gypsum Block, Plastered one side	.28
4" Gypsum Block, Plastered both sides	.27

FLAT ROOFS WITH BUILT-UP ROOFING

Deck Material	No Ceiling	Metal Lath and Plaster Ceiling
Precast Cement Tile	.81	.43
Precast Cement Tile, 1" Rigid Insulation	.24	.19
2" Thick Concrete	.82	.42
2" Thick Concrete, 1" Rigid Insulation	.24	.19
4" Thick Concrete	.72	.40
4" Thick Concrete, 1" Rigid Insulation	.23	.18
1" Wood	.49	.32
2" Wood	.32	.24
Flat Metal Roofs	.95	.46
Flat Metal Roofs, 1" Rigid Insulation	.25	.19

FRAME FLOORS AND CEILINGS

Hardwood and Pine Flooring on Joists, no Ceiling	.34
Hardwood and Pine Flooring on Joists, Wood Lath and Plaster Ceiling	24
Rough Pine Floor, Wood Lath and Plaster Ceiling	28
No Floor, Lath and Plaster Ceiling	62
No Floor, Lath and Plaster Ceiling, 3⅝" Rock Wool Fill	079
No Floor, Lath and Plaster Ceiling, 1" Flexible Insulation	17
Pine Floor 3⅝" Rock Wool Fill, Lath and Plaster	063

24-1. U values for walls, ceilings, floors and partitions for various types of construction and for various thicknesses.

(American Society of Heating and Air Conditioning Engineers)

24-4. COOLING LOADS

There are definite sources for heat gain in warm weather:

1. Heat leakage into the building.
2. Air leakage into the building or ventilation air.
3. Sun load.
4. Heat from appliances.
5. Heat gain from occupants.

Heat gain is the term applied to heat gained by a space that is being cooled, and the heat must be removed to keep the temperature and humidity at the values desired.

This heat gain is produced by heat conduction through the walls, ceilings, floors, windows, and doors of the enclosure. Also heat moves into the room by way of infiltrated air. The people or any animals in the room also give off heat. Miscellaneous sources of heat are electrical devices (lights and motors), gas burning devices, steam tables, etc. Another source of heat that may be considerable in some cases is heat from the sun or sun effect.

24-5. HEAT LEAKAGE

Heat leakage is that heat that is conducted through the walls, ceilings, and floors of the building. If one knew the heat that would pass through a wall for each sq. ft., for each degree F., and for each hour, it would be only necessary to find the area of each type of surface through which the heat is leaking, and by simple multiplication to find the total heat leakage. All building materials have been carefully tested in laboratories and from this data one can obtain the amount of heat that will transfer through almost any enclosure surface built today. This heat transfer is called conductivity, and as there are three general conditions, the following terms are used.

K is a letter representing the Btu that will be seen through one sq. ft. of substance in one hour if there is a temperature difference of one degree Fahrenheit, and if the insulation is one unit thick.

Thus the units of K are Btu/sq. ft./F/hours/thickness.

The letter C is used to mean the heat transfer through a wall made of different substances.

$$\frac{1}{C} = \frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{X_3}{K_3}$$

$$C = \frac{1}{\frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{X_3}{K_3}}$$

The letter U is almost the same as C, but the value represents the additional resistances of an air film on each side of the surface.

$$U = \frac{1}{\frac{1}{f_1} + \frac{X_1}{K_1} + \frac{X_2}{K_2} + \frac{X_3}{K_3} + \frac{1}{f_2}}$$

Where f_1 is the heat transfer through the dead air film.

The U value is the one always used when determining the heat transfer through an enclosure surface

U = Btu/sq.ft./F/hour

U is the symbol for leakage air to air through a complex structure. The U value for almost every construction can be obtained from the "Guide," a reference book published by the Society of Heating and Air Conditioning Engineers. Figure 24-1 is a simplified table for some of the more common constructions.

Therefore, if one knows that the U factor is .25, that the design temperature conditions are 70 F. indoors and 0 F. outdoors, and that the area is 1200 sq. ft., one may calculate the heat load as follows:

Heat Load = Area x Temp. Diff. x U factor

The total area in this case is

8' x 14' = 112 sq. ft.

but the heat transfer through the win-

State	City	Extreme Temperatures		Mean Temperatures		Design Conditions		
						Winter	Summer	
		Low	High	January	July	Dry Bulb	Dry Bulb	Wet Bulb
Ala.	Mobile	— 1°	103°	52°	81°	15	95	79
Ariz.	Phoenix	16	119	51	90	25	110	75
Ark.	Little Rock	—12	108	41	81	5	96	78
Calif.	San Francisco	27	101	50	58	30	90	65
Colo.	Denver	—29	105	30	72	—10	95	72
Conn.	New Haven	—14	101	28	72	0	95	75
D. C.	Washington	—15	106	33	77	0	96	78
Fla.	Jacksonville	10	104	55	82	30	95	79
Ga.	Atlanta	— 8	103	43	78	5	95	78
Idaho	Boise	—28	121	30	73	—10	100	70
Ill.	Chicago	—23	103	25	74	—10	95	75
Ind.	Indianapolis	—25	106	28	76	— 5	96	76
Iowa	Dubuque	—32	106	19	74	—15	96	75
Kan.	Wichita	—22	107	31	79	0	100	75
Ky.	Louisville	—20	107	34	79	0	98	77
La.	New Orleans	7	102	54	82	25	96	80
Maine	Portland	—21	103	22	68	—10	92	75
Md.	Baltimore	— 7	105	34	77	0	96	78
Mass.	Boston	—18	104	28	72	— 5	95	75
Mich.	Detroit	—24	104	24	72	—10	95	75
Minn.	St. Paul	—41	104	12	72	—20	95	75
Miss.	Vicksburg	— 1	104	48	81	15	96	80
Mo.	St. Louis	—22	108	31	79	0	98	79
Mont.	Helena	—42	103	20	66	—20	90	68
Neb.	Omaha	—32	111	22	77	—15	100	75
Nev.	Winnemucca	—28	104	29	71	—10	95	70
N. C.	Charlotte	— 5	103	41	78	10	96	79
N. D.	Bismarck	—45	108	8	70	—25	98	70
N. H.	Concord	—35	102	22	68	—15	95	75
N. J.	Atlantic City	— 7	104	32	72	0	95	75
N. M.	Santa Fe	—13	97	29	69	0	92	70
N. Y.	New York City	—14	102	31	74	0	95	77
Ohio	Cincinnati	—17	105	30	75	0	98	77
Okla.	Oklahoma City	—17	108	36	81	0	100	76
Ore.	Portland	— 2	104	39	67	10	95	70
Penna.	Philadelphia	— 6	106	33	76	0	95	78
R. I.	Providence	—12	101	29	72	0	95	75
S. C.	Charleston	7	104	50	81	15	96	80
S. D.	Pierre	—40	112	16	75	—20	100	72
Tenn.	Nashville	—13	106	39	79	5	98	79
Texas	Galveston	8	101	54	83	25	95	78
Utah	Salt Lake City	—20	105	29	76	— 5	95	70
Vt.	Burlington	—28	100	19	70	—15	92	73
Va.	Norfolk	2	105	41	79	10	98	78
Wash.	Seattle	3	98	40	63	10	90	67
W. Va.	Parkersburg	—27	106	32	75	— 5	96	77
Wis.	Milwaukee	—25	102	21	70	—15	94	75
Wyo.	Cheyenne	—38	100	26	67	—15	92	70

24-2. Design conditions used for calculating heat loads for heating or cooling for various regions of the U. S. (American Society of Heating and Air Conditioning Engineers)

dows and doors is different. So their area must be taken away from the wall surface.

Window = 2' x 4' = 8' sq. ft.
Door = 3' x 7' = 21' sq. ft.
29 sq. ft.

The wall surface therefore will equal

112 sq. ft. - 29 sq. ft. = 83 sq. ft.

The heat transfer can now be determined.

Wall Q = .27 x 83 sq. ft. x 70 F.
= 12.41 x 70
= 868.7 Btu/hr.

Window Q = 1.16 x 29 sq. ft. x 70 F.
= 1.16 x 29 x 70
= 33.64 x 70
= 2354 Btu/hr.

As another example, a brick veneer wall, no insulation has a U of .27. This value means that .27 Btu will transfer through each sq. ft. of the wall for each 1 F. temperature difference in one hour.

This U value is based on a 15 mi./hr. wind on the outside and a 15 ft./min. draft on the inside wall surface.

The total heat Transfer (Q) = U x total surface x Temperature difference. Therefore, if there is 400 sq. ft. of surface and the temperature difference is 70 F.

Total Heat Transfer = .27 x 400 x 70
Q = .27 x 28000
Q = 7560 Btu per hour
= 1200 x 70 x .25
= 2100 Btu's per hour

The outdoor or ambient temperature is different for each locality. Figure 24-2 shows the design conditions for calculating heat loads for heating and cooling for various regions.

24-6. AREAS

Areas are usually measured on the inside dimensions of the building.

For rough estimates of the heat load, the complete building is measured as one unit. The areas measured are:

1. Walls
2. Windows
3. Ceilings
4. Floors

The walls are measured by taking the length and width of the house and the ceiling height. To determine the total surface area, first determine the distance around the house; this will be the length plus length, plus width, plus width (perimeter). When these values are added together and multiplied by the wall height, the total wall area is obtained. For example, a house 24' x 32' with an 8' ceiling has a total area of 32 plus 32 plus 24 plus 24 = 64 plus 48 = 112 ft.

112 ft. x 8 ft = 996 sq. ft.

This is the total wall area, and the window area must be subtracted. If the window area is 116 sq. ft., then the net wall construction is

996 - 116 = 880 sq. ft.

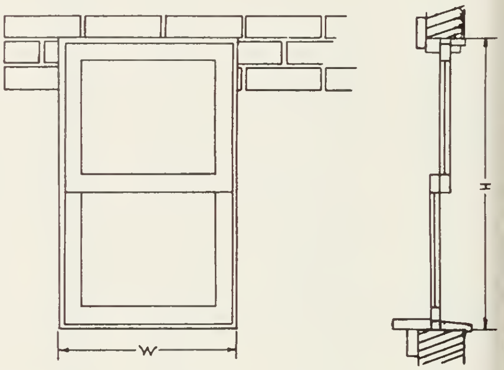
The ceiling area is the width times the length.

24' x 32' = 768 sq. ft.

The floor area will be computed the same as the ceiling. Note that wall closet areas, etc. are neglected.

Surface	Area	U valve	Temp.Diff.	Heat Leakage
Wall, gross	996			
Window	116	1.13	70	23176
Wall, net	880	.25	70	15400
Ceiling	768	.62	35	16666
Floor	768	.34	25	6528
			Total	61770

24-3. A typical heat load calculation for a 24 x 32 ft. home having an 8 ft. ceiling height.



24-4. A typical double hung window showing the window openings.

It is best to set up the total heat load calculations in tabular form. Figure 24-3 illustrates a typical heat load calculation for the above house. Note that the temperature difference for the ceiling is only 35 F. This is because the attic temperature is assumed to be 35 F., because the roof is an added insulation and keeps the attic temperature from equalling the outdoor temperature. The attic temperature can be accurately calculated by making the heat leaking into the attic equal the heat leaking out.

Ceiling area x (70-attic temp.) x U_c = Roof Area x (attic temp. -0 F.) x U_r.

The temperature in the basement is usually considered to be approximately 50 F.

24-7. WINDOWS AND DOORS

The area of the windows is measured by measuring the opening in the wall. In a brick veneer wall, this would be the distance to the brick edges. Figure 24-4. The windows maybe either single pane or double pane. The double pane is usually called storm sash although some companies are making double pane panels assembled at the factory. See table 29 - 1 for "U" value of windows.

24-8. CEILINGS

The ceilings are usually made with a plaster finish fastened to lath, which in turn is fastened to joists. Variations in construction using rock lath on other surface finishes will not change this calculation to any great extent. If the joists do not have a floor over them, or if there is no insulation between the joists, the heat leakage will be considerable.

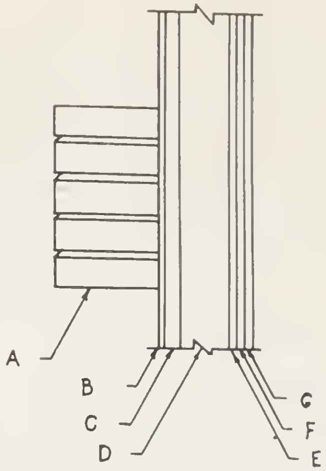
See Table 24-1 for "U" values for ceilings.

24-9. DESIGN TEMPERATURES

The design temperatures shown in Figure 24-2 are the result of considerable testing and the accumulation of much data. A study of the table reveals that the places requiring the largest heating plant would be Helena, Montana, and Peirre, South Dakota. Those places needing the least heat are San Francisco, California and Jacksonville, Florida. There are places colder and warmer than these places, and the local weather bureau or the local chapter of the Society of Heating and Air Conditioning Engineers can be contacted for local data.

It is always best to choose design ambient temperatures on the low side, because heating plants that are overworked cause excessive stack and chimney temperatures and may cause fires.

The design temperature is never as low as the lowest temperature recorded for the area, as these extreme lows are usually of short duration. The residual heat in the building enables the design temperature to handle the load.



24-5. A brick veneer wall construction. A. Brick; B. Outside vapor barrier; C. Sheathing; D. Stud and insulation; E. Inside vapor barrier; F. Lath; G. Plaster.

24-10. WALL CONSTRUCTION

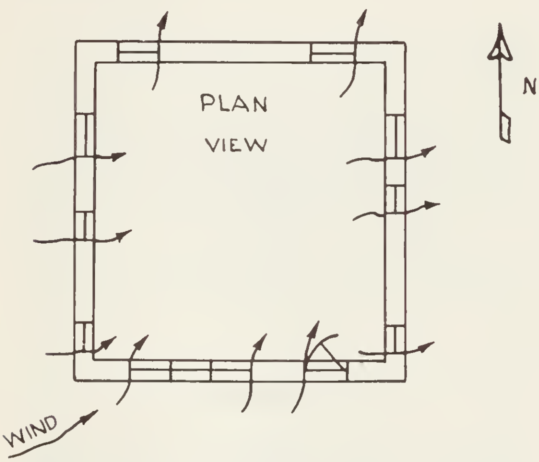
The wall construction of a building has been altered in the past few years to reduce heat leakage and to reduce moisture passage through the wall structure. Figure 24-5. During the heating season, the inside vapor barrier (E) is all that is necessary, while in summer this outside vapor barrier (B) is necessary. These barriers should be as tightly sealed as possible even to the extent of tarring the breaks in the seal. The barriers may be made of tarred paper or aluminum foil. The aluminum foil has a reflection value as well as being a vapor tight seal.

24-11. UNHEATED SPACES

Many spaces in a building are not heated. They receive their heat from heat leakage through the partitions, ceilings, and floors. These spaces are usually assumed to be at a temperature half the distance between the indoor temperature and the ambient temperature.

24-12. INFILTRATION

Because buildings are not air tight, air leaks into a building if there is any air pressure difference, and the air also leaks out during these times. The air pressure difference is usually caused by wind. Those parts of the building that the wind is pressing against are those areas through which the air leaks in. The remaining areas are those areas through which the air leaks out. Figure 24-6.



24-6. A diagram illustrating how wind direction affects air leakage into and out of a house.

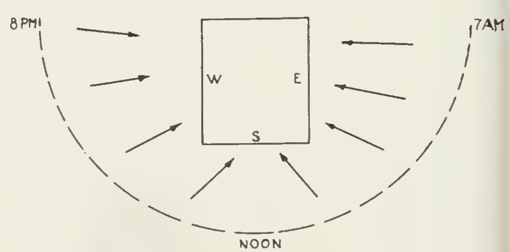
During the heating season, the cold air that filters in must be heated, and the air that leaks out represents lost heat. During the cooling season, the warm air that filters in must be cooled, and the cooled air that filters out is lost. If the building can be sealed, this infiltration and exfiltration can be minimized, but one must be careful to always provide enough fresh air for ventilation purposes.

Type of Space	No. of air changes/hr.
1 side exposed	1
2 sides exposed	1 1/2
3 sides exposed	2
4 sides exposed	2
Entrances	2-3

24-7. Approximate number of air changes per hour for various room exposures.

Another method to prevent infiltration is to maintain a positive air pressure within the building, and thus air filters out at the cracks and openings in the building. This practice necessitates a special fresh air intake, and this air must be conditioned before it is admitted to the building.

Infiltration can be calculated on the total volume of the building basis or by measuring the length and size of all the cracks in the building. Figure 24-7 lists the air changes in buildings. If a building has a volume of 10,000 cu. ft., it will have at least 10,000 cu. ft. of fresh air filter in per hour. If six people occupy this space, there is $10{,}000 \div 6$ or 1667 cu. ft. per hour for each person or $1667 \div 60 \simeq 27.7$ cu. ft.



24-8. The sun rays and their impact on the walls of a building during a 12 hour period.

per minute which is a very good ventilating value. If this building is constructed with vapor barriers, and all doors and windows are fitted with weather stripping, this air change will be reduced considerably. It may even be reduced to the point of unsafe ventilation.

24-13. SUN HEAT LOAD

The heat energy that comes from the sun adds considerable to the total heat load during the summer. The sun's rays shine on the east wall, the south wall, the west wall, and on those roof sections that are open to its rays. Therefore, the heat from the sun must be considered on the east wall in the morning, on the south wall all day long, and on the west wall in the afternoon. Figure 24-8.

The sun releases different amounts of heat to surfaces depending upon the part of the world in which the building is located. The approximate maximum

Exposure	Heat Absorption B.T.U./hr./sq.ft.
Southwest	110
West	100
South	75
East	55
Single skylights	110
Double skylights	60

24-9. Heat absorption from the sun when the sun is shining on windows.

heat pick-up or heat gain from the sun is 330 Btu per hr. per sq. ft. This condition would exist for a black surface at right angles to the sun's rays near the equator (tropic). Any other color or any surface at an angle to the sun's rays will receive less than this amount of heat.

At the 42nd parallel, a line going through New York City, Cleveland, Salt Lake City, etc., the maximum heat from the rays is about 315 Btu per hr. per sq. ft. Much of the heat from the sun is reflected back into the atmosphere. That amount of heat gain through windows that must be removed with air conditioning cooling is listed in Figure 24-9.

If the windows are protected with awnings, it is generally agreed that using an outside temperature of 15 F. higher than normal takes the sun sufficiently into account. The sun effect on walls is also taken care of by adding 15 F. to the ambient temperature.

The approximate values obtained by using the 15 F. are practically usable. However, there are many special cases that require careful study. Of considerable interest is the changing relative position of the sun to the surfaces of the building and the time lag of this heat reaching the interior of the building.

24-14. HEAT LAG

When a substance is heated on one side, it takes time for the heat to travel through the substance. This time is called time lag. When the sun heats an outside wall of a building, several hours elapse before this heat reaches the inner surfaces of that wall. In normal buildings this time varies between 3 and 4 hours. If the wall is insulated well enough, or if the wall is thick enough, the sun will be gone by the time the heat penetrates or "soaks" through. In the Southwest, adobe walls are so thick that the sun heat moves into the wall during the sunshine time and then reverses itself and travels out again during the evening, because the outdoor temperatures fall below the indoor temperatures during the night. Figure 24-10.

Therefore, except for windows, one must remember that the heat from the sun on an east wall actually reaches the rooms as follows:

Sun 8 to 9 goes into the rooms 11-12
9 to 10 goes into the rooms 12-1
10 to 11 goes into the rooms 1-2

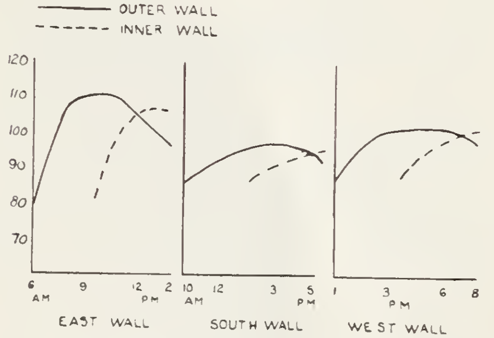
Likewise, the west wall that receives sun rays from 4 to 7 P.M. acts as follows:

Sun 4-5 goes into the rooms 7-8
Sun 5-6 goes into the rooms 8-9
Sun 6-7 goes into the rooms 9-10

It is also because of this heat lag that the rooms are being heated even after the sun goes below the horizon, and when the outdoor temperature drops. Many people complain of the uncomfortable heat in their bedrooms, etc., up to as late as 12 midnight and even 1 and 2 A.M.

24-15. ATTIC FAN

One inexpensive solution to this delayed heating is the attic fan. The attic fan exhausts the air of the building allowing the cooled evening outside air to free itself into the house. This cooling effect partly overcomes the effect of the heated walls and ceiling. However, this exhaust fan system does have the disadvantage of bringing considerable outdoor dust into the building.



24-10. The lag in noticeable interior wall temperature following exposure to the sun.

24-16. HEAT SOURCES IN BUILDINGS

During the heating season, the heating plant is aided by many other sources of heat. Practically all the energy expended in the building finally becomes heat. These heat sources are usually ignored when figuring the heat load in the winter, because they are small compared to the total heat load in temperate zones and are an additional safety factor.

However, when one is figuring the summer heat load or the cooling heat load, all sources of heat energy must be carefully considered. Such items as the heat released by human beings, stoves, lights, electric motors, etc., must all be considered in the final heat load. Figure 24-11. Notice that the two sources of heat are itemized, the sensible heat gain and the latent heat gain. Because the efficiency of an electric motor is less when the motor is small, the $\frac{1}{2}$ HP motor releases 2100 Btu/hr when a $\frac{1}{2}$HP ideal motor would release only 1273.

24-17. INSULATION

A large number of different insulations has been developed for buildings. It is essential that the insulation reduce heat loss by conduction, convection, and radiation. It is also important that vapor barriers be included in the insulation or in the walls to reduce moisture travel through the wall.

The insulation must have sufficient strength so that it can support itself and will not shrink or settle. It must not deteriorate in the presence of moisture, and it must not have any unpleasant odor. It should be vermin proof.

The type of insulation depends on the method of application. For example, bulk easy flowing insulation can be placed between the studs of a building already constructed. Rigid insulation can be used as a part of the building wall, such as the plaster base or as a substitute for the ship lap sheeting.

Flexible insulations are easily installed and conform to any irregular-

Device		Heat-B.T.U./hr. Sensible	Latent
Electric	Lights/kwhr	3415	
	Motors, electric/H.P. in room - 1/2	4200	
	- 3	3700	
	- 20	2950	
	Motors, electric/H.P. out of room 1/2	1700	
	3	1150	
	20	400	
	Stoves, electric/kwhr	3415	
Gas	Natural gas/cu.ft.	1100	300
	Artificial gas/cu.ft.	550	675
General	Heat from meals/meal	36	
	Steam tables/sq.ft.	400	800
	Humans		140
	Sitting	370	
	Working	700-1500	
	Dancing	2000	

24-11. The heat released by various energy sources within a building in Btu per hour.

ities in the construction. Batts of rock wool and blankets of pulverized wood are examples of this practice. It is exceedingly important that all insulations that are hydroscopic (moisture absorbent) be hermetically sealed. Even those insulations not affected by moisture should be vapor sealed, as the insulation will lose much of its insulating value as it fills up with moisture.

24-18. UNIT AIR CONDITIONER HEAT LOAD CALCULATIONS

A relatively easy method to use when one wants to calculate the summer heat load per hour on a room is tabulated as follows:

Name__________________
Address__________________
Zone________ Phone__________
Space used for __________________
Interior room dimensions:
Length______ Width______ Height____
Windows:
No.____ Facing____ Size____ X____
No.____ Facing____ Size____ X____
No.____ Facing____ Size____ X____

Window Load

1. Sun exposed (interior shades) west side____sq. ft. x 60 = ____
2. Sun exposed (interior shades) south side____sq. ft. x 40 = ____
3. Sun exposed (awnings)____ sq. ft. x 35 = ____
4. East exposure, north exposure, or shaded____sq. ft. x 15 = ____

Wall Load

1. Sun exposed--south and west walls ____sq. ft. x 8 = ____
2. East or North exposure ____sq. ft. x 5 = ____
3. All exposures, thin walls ____sq. ft. x 10 = ____
4. Interior walls ____sq. ft. x 4 = ____
5. Interior glass partition ____sq. ft. x 10 = ____ ____

Floor Load

____sq. ft. x 3 = ____

Ceiling Load

1. Occupied above ____sq. ft. x 3 = ____

2. Insulated roof
_____sq. ft. x 8 = ____
3. Uninsulated roof
_____sq. ft. x 20 = ____ ______

Ventilation Load
_____cu. ft. x .4 = ________

Occupancy Load
No. of people_______ x 400 = ______

Miscellaneous Load
Electrical watts_____x 3.4 = ______
Other x = ______

Total Btu. per hour_______________

The average window type comfort cooling unit will adequately handle the heat loads as follows:

Up to 6000 Btu/hr.	= 1/2 H.P.
6000 - 9000	= 3/4 H.P.
9000 - 11,000	= 1 H.P.

The multipliers in the tabulation are obtained by multiplying a typical A factor by the temperature difference. For example, the windows (no sun) have a U factor of 1.25 and if the temperature difference is about 12 F., therefore the multiplier becomes 15.

24-19. REVIEW QUESTIONS

1. What are the two main sections of the heating load?
2. What are the main sources of heat that cause cooling load?
3. What are the variables for calculating heat leakage?
4. How are window sizes dimensions chosen?
5. Is the heating design outdoor temperature the coldest temperature recorded?
6. How are storage closets handled when figuring the heating load?
7. How are unheated spaces accounted for when figuring heating loads?
8. Describe infiltration and exfiltration.
9. What is meant by having a positive air pressure in the building?
10. What building walls are affected by the sun (42nd parallel)?
11. How is the sun effect usually included in cooling load calculations?
12. Does sun load on the walls and windows affect the heat load at the same time?
13. What is heat lag in a building?
14. Describe the insulation ability of one sheet of aluminum on the basis of conduction, convection and radiation.
15. What is an air film?

Chapter 25

AIR CONDITIONING SYSTEMS AND CONTROLS

Air conditioning systems are dependent on heat sources, cooling devices, filtering devices and the control of humidity. The training in each of these devices and the operation of their individual controls constitute the information contained in this chapter.

25-1. TYPES OF SYSTEMS

A complete automatic air conditioning system that satisfactorily performs all the functions of air conditioning is difficult to achieve. Most of the systems available today are compromises in one form or another. The two most difficult results to obtain are air cleaning and proper humidity.

Most air conditioning systems are partial systems. That is also the unit for heating, humidifying, cleaning, and distributing; or, the unit is for cooling, dehumidifying, cleaning, and distributing. Most of the systems are only semi-automatic, or only some of the operations are completely automatic.

25-2. AIR-CONDITIONING EQUIPMENT

Air-conditioning equipment may be divided into six headings:

1. Heating facilities
2. Humidifying equipment
3. Filtering and cleaning equipment
4. Circulating equipment
5. Dehumidifying equipment
6. Cooling equipment

Normally, not all of these devices are in use at the same time. During the summer we do not use heating or humidifying equipment, but rather use the cooling and the dehumidifying equipment. In the winter we use the heating and the humidifying equipment. The other parts such as filtering, cleaning equipment, and circulating equipment are used the year round. Complete air-conditioning equipment may be constructed in three different forms:

1. The entire air conditioning plant may be located in the basement and conditioned air circulated throughout the building.
2. The heating and cooling equipment (refrigeration) may be located in the basement, but pipe lines constructed throughout the building carry the heating and cooling mediums to the various rooms. Small ducts in this case usually provide ample ventilation and air circulation.
3. Unit installations have a complete plant located in each room. Such plants usually contain humidifying and dehumidifying equipment, as well as heating, cooling, and air circulating equipment, although the heat source may be

outside the room if the installation uses steam or hot water for its heating medium.

25-3. AIR-CONDITIONING STRUCTURES

It has been predicted that air-conditioning will be a tremendous factor in our economic growth. However, the air-conditioning of many homes and other structures presents some insulation problems which must be solved in order that the operating cost of the air-conditioning equipment will not be too high. Since air-conditioning implies controlled temperature and humidity, such factors as heat leakage by conduction or convection are important factors.

Air-conditioned structures should be very well insulated in order to eliminate conduction through the walls. All dead air spaces in walls, particularly outside walls, should be thoroughly sealed in order to eliminate convection. Roofs and ceilings particularly should be heavily insulated. For summer air-conditioning in addition to the above, it is often desirable to put on awnings to keep the sun from shining through the windows, and increasing the heat load on the cooling plant. If possible, roofs should be painted a light color in order that as little radiant heat may be absorbed as possible. Double windows should be installed if a very great temperature difference is to be maintained. All doors and windows should be kept closed in order that very little of the conditioned air will be allowed to escape; however, an adequate and controlled air change is necessary to keep the air-conditioned space healthful.

25-4. HEATING EQUIPMENT FOR AIR-CONDITIONING

Heating equipment must be entirely automatic in its operation. The source of the heat may be coal, oil, gas, or the heat pump and the choice will be governed largely by the location and equipment available. In plants in which a central plant is built into the basement and the air circulated throughout the structure, it will be necessary to carefully filter and clean the air as it is circulated. With steam heating plants, radiator or heating coils are usually incorporated in the room air-conditioning units; and the necessary humidifying and filtering are done in each room unit.

25-5. COAL FURNACES

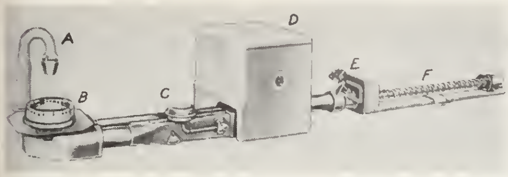
One of the oldest fuels used for heating is coal. There are two kinds of coal, bituminous (soft) and anthracite (hard). The soft coals are more commonly used. When completely burned, this coal will release between 11,500 to 14,500 Btu/lb. The heat is formed by the oxidation of carbon and hydrogen. Most coal has an ash content. The ash varies from $3\frac{1}{2}$ to 13%.

Hand fired coal furnaces are not very efficient. They vary between 25 to 50% efficiency. Stoker fired furnaces vary between 50 and 80% efficiency.

A stoker which feeds its coal from the coal bin automatically is shown in Fig. 25-1. It is electrically controlled by a thermostat, a limit control, and a controller which keeps the fire alive in mild weather. The worm F driven through a gear reduction in D removes coal from the coal bin, feeds it to the tuyeres B where combustion takes place. A is special down draft jet or duct which increases combustion efficiency and helps maintain a better mild weather low fire. C is a pressure operated draft control. It controls the volume air as needed and closes during off cycles to aid banking the fire.

The housing D contains the electric motor, the gear reduction unit to obtain correct worm speeds and the belts and

fan for the forced draft. The access plate at E enables one to easily remove any obstruction that may lodge in the feed worm. Shear pins are installed in the gear reduction drive to disconnect



25-1. A stoker. This unit has an automatic feed from the bin. A. Air jet; B. Tuyeres; C. Draft control; D. Housing containing motor, gear box, and fan; E. Access plate; F. Coal bin worm.
(Iron Fireman Mfg. Co.)

the motor from the worm if the turning load becomes excessive. Fig. 25-2 shows a stoker installed in a furnace and a coal bin.

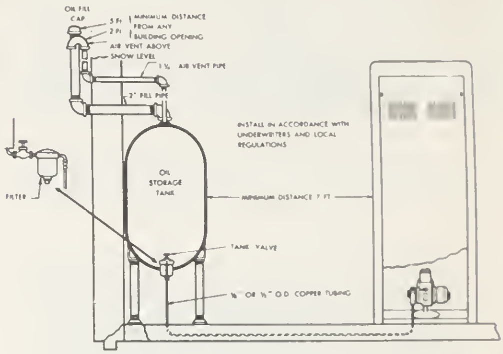
25-6. OIL FURNACES

A very popular method of heating residences and small commercial buildings is the oil fired furnace. The two most common oil burners are the gun type, and the rotary type.

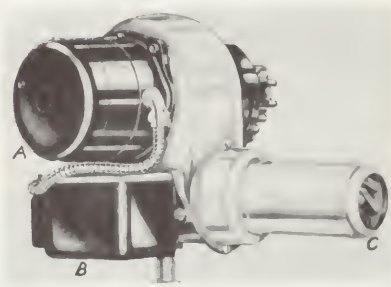
The gun type burner forces oil under pressure through definite size orifices. The oil is broken into finely divided particles (atomized) and it is then mixed with air that is forced into the combustion chamber by a blower in the same unit.

A typical installation diagram of a gun-type oil burner is shown in Fig. 25-3. This installation has the oil storage tank located in the basement.

The oil is fed under a definite pressure, 80 to 100 psig, to a nozzle. Air is forced into the furnace through a tube that surrounds this nozzle. The air

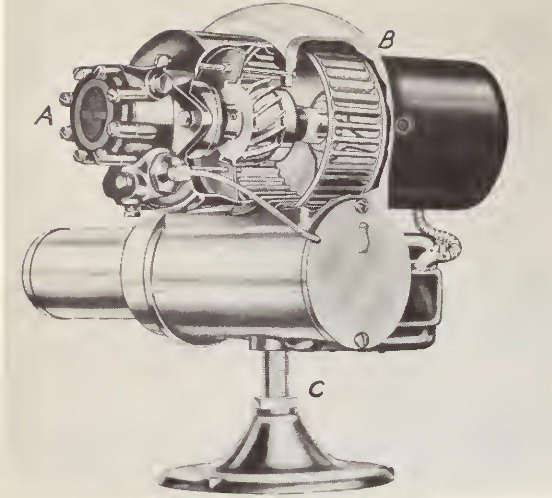


25-3. A typical oil storage tank installation in a basement.
(Webster Electric Co.)



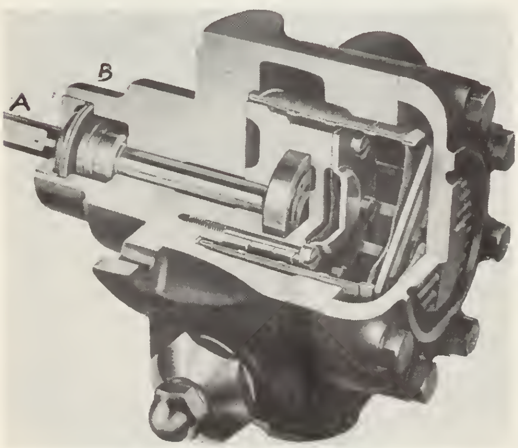
25-4. A medium pressure gun type oil burner. A. Motor; B. Ignition transformer; C. Air and oil nozzles.
(Gilbert & Barker Mfg. Co.)

25-2. A cross sectional view of a stoker installed in a furnace and a coal bin.
(Iron Fireman Mfg. Co.)



25-5. A sectional view of a gun oil burner. A. Two stage oil pump; B. Air blower; C. Adjustable stand. (Fedders-Quigan Corp.)

is usually twisted in one direction and the oil is given a twist in the opposite direction. The nozzle should be carefully centered in the housing. The ignition transformer furnishes a high tension spark between two electrodes located near the front of the nozzle. See Fig. 25-4 and Fig. 25-5. The burner shown has a two-stage oil pump. Note that the same electric motor drives the pump and the air blower.



25-6. A single stage rotary fuel pump for gun type oil burners. A. Shaft; B. Seal. Note the large screen mounted around the pump. The pressure regulator is located underneath. (Sundstrand Machine Tool Co.)

The oil pump has a pressure regulator built into it. This regulator not only controls the oil pressure but it shuts off the oil flow to the nozzle the instant the unit shuts off and prevents oil dripping at the nozzle.

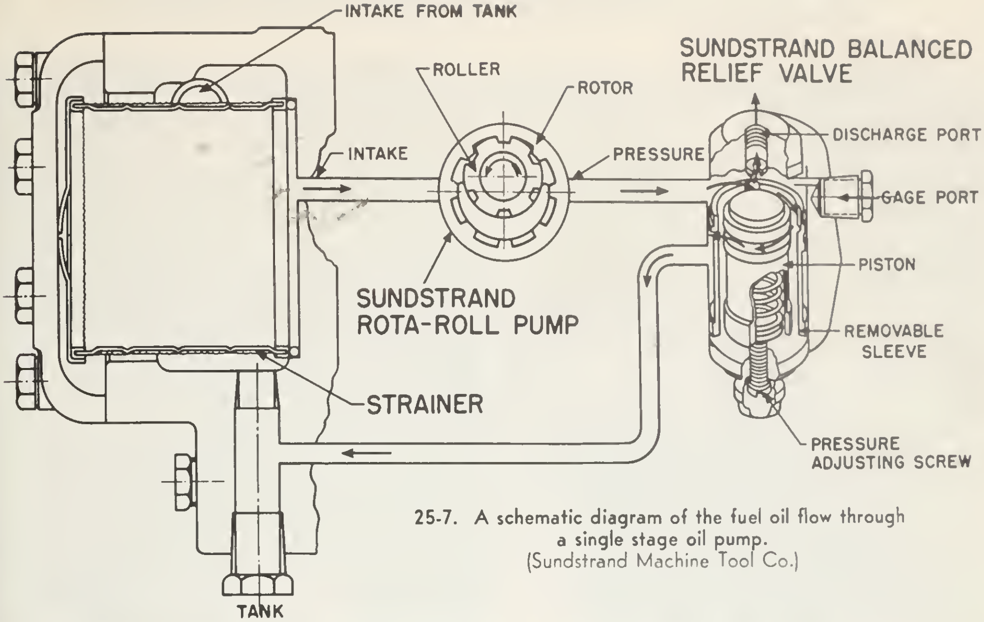
Several types of oil pumps are used in the gun oil burners including the gear type, and the rotary type. These pumps come in either single stage or two stage models. The single stage pump is used in the single pipe system, Fig. 25-6.

This system carries the fuel oil from the tank, through the screen, and into the pressure regulator and relief valve. The pump is rotating contra-clockwise and the oil flow is from left to right. The oil leaves the upper center of the pressure regulator and passes to the gun nozzle, Fig. 25-7.

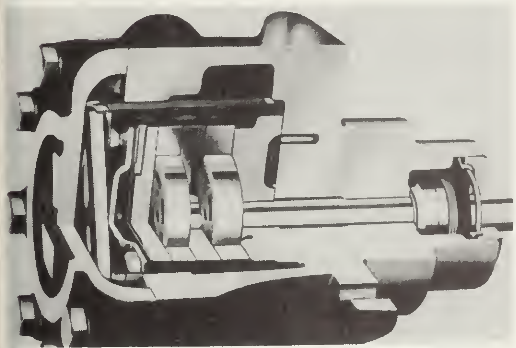
Many systems use the two-stage fuel oil pump. It is a necessary pump when the two-pipe system is used and part of the oil is returned to the fuel tank. This unit is necessary where the pump has to lift the oil above the bottom of the fuel tank, Fig. 25-8. Its principle of operation is shown in Fig. 25-9. The intake from the tank is at the top. The oil passes through the first stage into the regulator and back to the tank. It can handle both fuel oil and air. The second stage removes only oil from the strainer chamber and pumps it into the regulator. When sufficient pressure is created the regulator will open and feed to the oil nozzle. Excess oil is returned to the strainer chamber.

Details of the relief valve can be seen in Fig. 25-10. The oil pressure creates a force against the piston. When this force equals the compression spring force, the piston will move to the right and permit oil to flow to the nozzle.

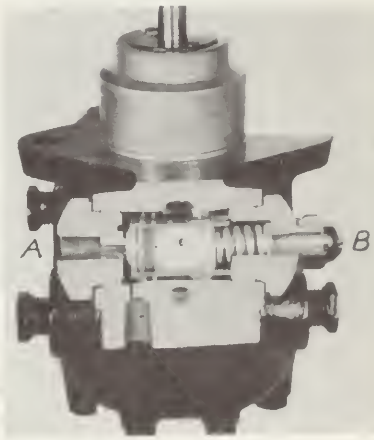
The gear type oil pump is also available in both the single stage and two stage models. Fig. 25-11 shows the external appearance of a single stage



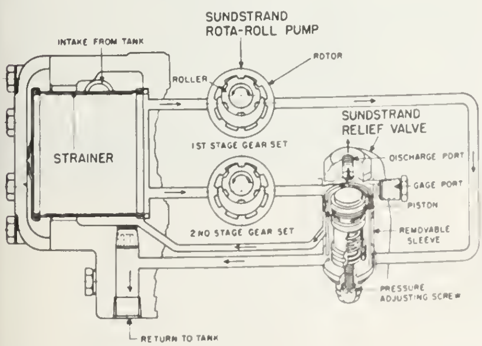
25-7. A schematic diagram of the fuel oil flow through a single stage oil pump.
(Sundstrand Machine Tool Co.)



25-8. A two-stage fuel oil pump for two pipe oil burners.
(Sundstrand Machine Tool Co.)



25-10. A cutaway of the relief valve for a fuel oil pump. A. Oil outlet to the nozzle; B. Pressure regulating screw.
(Sundstrand Machine Tool Co.)

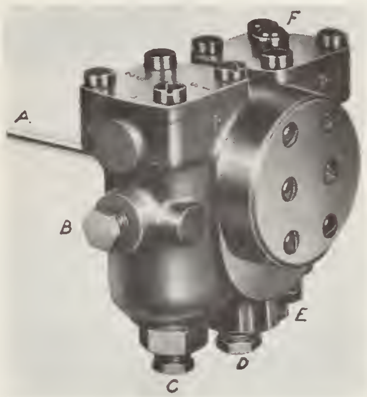


25-9. A schematic diagram of the operation of a two-stage fuel oil pump using a two pipe system.
(Sundstrand Machine Tool Co.)

gear pump. The operation of this single stage pump is shown in Fig. 25-12. The fuel oil passes through the strainer (D) out through the silencer orifice (O) into the vacuum chamber (A). It passes into the gear pump, then enters the pressure regulator. When sufficient pressure is produced the piston valve is raised and oil flows to the nozzle. Cushions are used to insure more even oil flow (B). If the pressure tends to rise, the piston valve guide will move up more and the excess oil will return

to the bottom of the strainer chamber to be recirculated.

The gun type oil burner is a very efficient heating unit. However, it must be maintained carefully to give peak performance. An experienced service man should check, clean and adjust the system each year. Some of the important items to check are shown in Fig. 25-13.



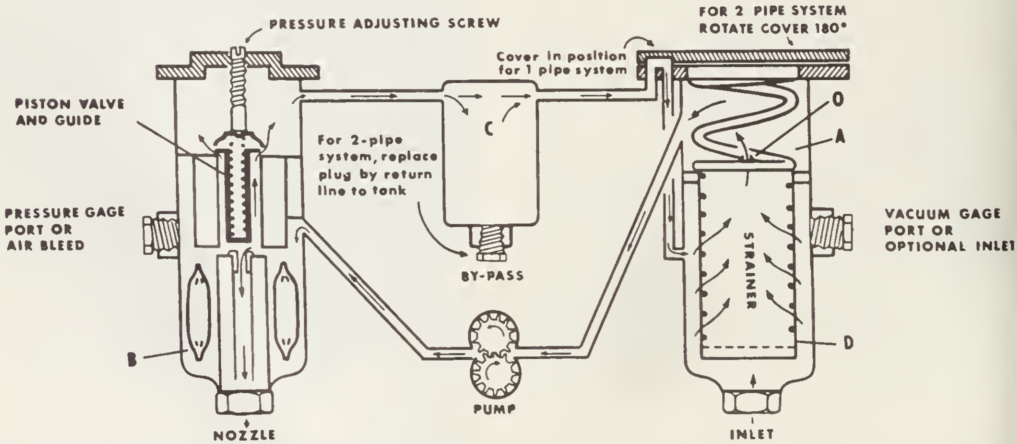
25-11. A single stage gear pump for gun type oil burners. A. Shaft; B. Alternate inlet; C. Inlet; D. By-pass; return pipe is connected here for two pipe system; E. Nozzle pipe connection; F. Pressure adjusting screw. The pressure gauge fitting is just above the nozzle fitting on the far side.
(Webster Electric Co.)

Gun type oil burners are also available in low pressure models. In these units the oil is mixed with air before it reaches the nozzle or the oil is aided in its atomizing by a slinger arrangement. The viscosity of the oil used is important. Viscosity means the ease of flow. Important things to consider are the impurities in the oil and the quantity of heavy carbons in the oil. Such impurities as sulphur form corrosive chemicals in the stack.

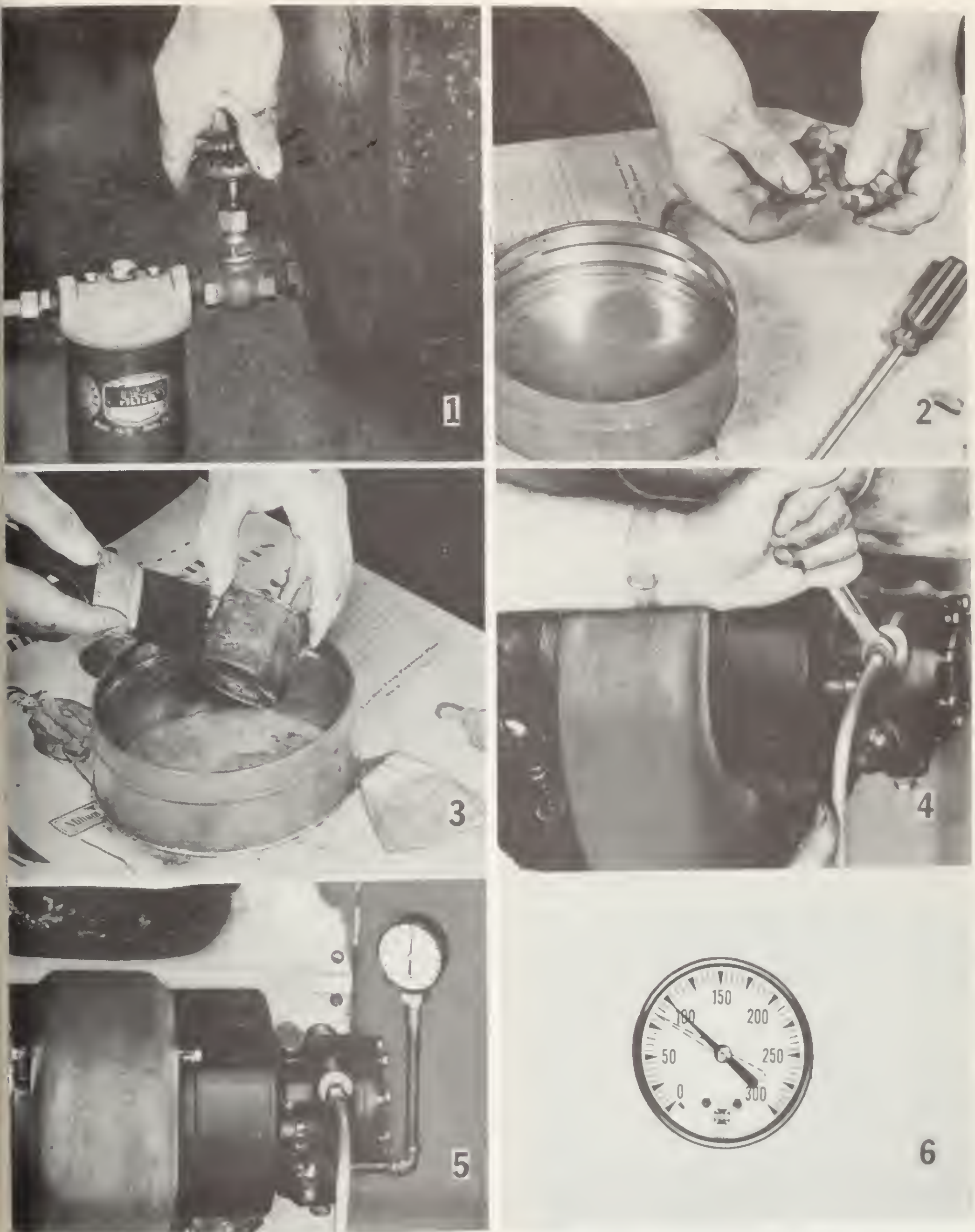
Oil has a heating value of approximately 140,000 Btu/gal.

It is important to remember that oil will not burn while it is in the liquid form. It must be vaporized and turned into a gas. To vaporize oil heat must be added to the oil (latent heat of vaporization). The oil will turn into a gas quicker and easier if it is finely divided (sprayed). This spraying process is called atomizing. The gun type oil burners accomplish the atomizing by forcing oil into a twisting, spiralling, and turbulent air stream. A small amount of heat (electric spark) will turn a few of the finely divided particles into gas and the burning will start.

In the rotary burner the oil is



25-12. A schematic diagram of the oil flow in a single stage gear type fuel oil pump. A. Vacuum chamber; B. Oil pressure cushions; C. By-pass chamber; D. Strainer; O. Silencer orifice.
(Webster Electric Co.)



25-13. Six main items to check at the start of each heating season. 1. Check the shut-off valve and line filter. Replace or clean cartridge in line filter if dirty. Be sure to open shut-off valve. 2. Check the nozzle assembly. Clean the nozzle according to manufacturer's recommendation. 3. Check the strainer. Clean the strainer using clean fuel oil or kerosene. 4. Check the connections. Tighten all the connections and fittings in the intake line and unused intake port plugs. 5. Check the efficiency. Insert the pressure gauge in the gauge port. Reasonable flame at 150 psig. Reset the valve to the original setting to prevent over firing. 6. Check the cut-off. Insert the pressure gauge in the nozzle port. Upon shut down the pressure should drop approximately 15 psig. If the pressures drop to 0 psig. the cut-off seat may be damaged.
(Sundstrand Machine Tool Co.)

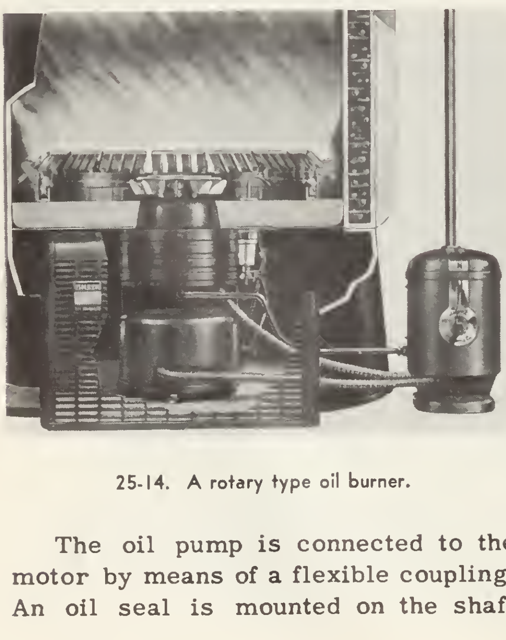
thrown, by centrifugal force from a motor driven rotary disc or slinger, against red hot stainless steel plates which vaporizes the oil completely. The combustion takes place at the point of vaporization and a very clean flame results, Fig. 25-14.

Space type oil burners use a "pot" type burner. The level of oil in the burner pot is controlled by a float and needle valve similar to the float and needle in an automobile carburetor. Vaporization takes place from the heated surface of the oil in the pot.

The main parts of a pressure or gun type burner are: the motor, the oil pump, the fans, the nozzle, the air tube, and the ignition system.

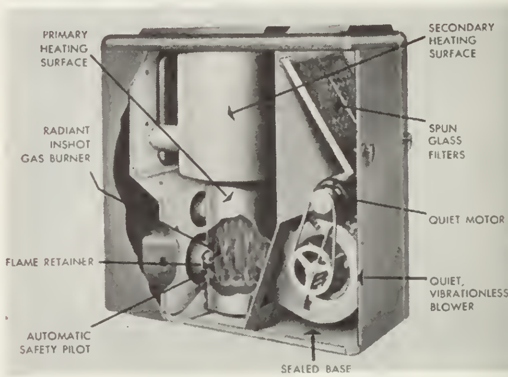
The motor is usually a split-phase 1/6 H.P. motor that provides power for both the fan and the fuel pump. It must be oiled at least once each six months. The motor is electrically connected to the master oil burner control and uses 110-V-60 cycle electricity.

The fan is usually the radial flow type and it has adjustable air inlet openings. These openings are adjusted until the flame burns a yellow color.



25-14. A rotary type oil burner.

The oil pump is connected to the motor by means of a flexible coupling. An oil seal is mounted on the shaft where the shaft enters the oil pump body. An oil inlet fitting is mounted in the pump housing and a strainer is mounted in the inlet. This strainer usually is made of Monel metal and is 100 mesh. It can be cleaned with a small quantity of thinner. The pump then imposes a pressure on the oil and moves it through a pressure regulator to the nozzle tube. The pressure regulator is adjustable and it is usually adjusted to 100 psig pressure. These



25-15. A gas fired furnace burner.

valves open quickly and close quickly to prevent oil drip at the nozzle. Any excess pressure is by-passed back to the inlet of the oil pump or in the two pipe system the excess is returned to the storage tank.

Oil pumps are either one stage or two stage. That is, the single stage uses one pump while the two stage has two pumps in series. Both gear pumps and rotary pumps are used. The single stage pump is used when the oil storage tank is above the oil pump. The two stage pumps (double line) are used when the fuel storage cylinder is below the oil pump.

An oil tube carries the oil to the burner nozzle. The electrodes and high tension wires are also carried on the oil tube. This tube must be carefully mounted in the air tube to insure that the nozzle is in the exact

center of the air tube.

Oil burners need approximately 40% excess air.

25-7. GAS BURNERS

Gas is being used at an ever increasing rate as a heating fuel. The gas is piped into the building. It is usually fed to the furnace at a 4 to 6 in. water column pressure. A pressure regulator reduces the pressure to approximately 2 in. water and a solenoid valve turns the main gas flow to the furnace burners on and off. This solenoid valve is operated from the house electrical current either from the line direct or through a transformer operating at a reduced voltage. Some solenoid valves are operated by the current generated by a thermocouple located near the pilot light; these do not require any connection to the house current.

The burner may be made of steel pipe or a casting. It may be either of the multiple jet or orifice type or it may be the one opening type with a deflector plate, Fig. 25-15.

The natural gas most commonly used has a heating value varying between 950 Btu/cu. ft. to 1200 Btu/cu. ft. This gas contains approximately 80 to 95 percent methane, up to 5 percent carbon dioxide and up to 14 percent nitrogen. Manufactured gas has a heating value of about 525 Btu/cu. ft.

The burners are of simple design. The gas is fed through an orifice and is mixed with a certain amount of air (primary air). The mixture passes to the burner orifices where combustion takes place and where the gas mixes with the secondary air. As much as 35 percent excess air is fed to the burner to insure thorough combustion.

Because both oil and gas contain small amounts of sulphur and because one of the products of combustion is water (steam) one must keep the stack or chimney warm enough to prevent condensation. If condensation takes place sulphurous acid is formed causing corrosion.

Practically all cities have code requirements for the installation of heating equipment. It is very important that this code be known and followed, otherwise unsafe conditions may exist.

25-8. ELECTRICAL HEATERS

Electricity can be used for heating. The electricity can be used to heat the air by means of resistances. Heating directly with electricity is expensive - one kilowatt hour releases 3.413 Btu/hr. It would cost approximately 60 cents per hour compared to 8 cents per hour for oil. (100% efficiency).

However, electricity can be used to drive a heat pump and the method produces three to four times the heat that the direct method produces. The heat pump will then operate at about 15 cents per hour in the above sample.

The heat pump is described in Chapter 26.

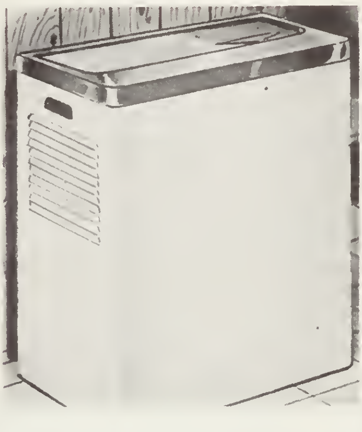
Electrically heated glass panels or wall panels may be used to serve as sources of auxiliary heat.

Some systems have been built that furnish 40 to 50% of the heat with radiant heat and the remainder by means of conditioned circulated air. These split systems prevent cold floors and/or cold walls while also providing sufficient conditioned air for comfort and health.

25-9. COOLING EQUIPMENT FOR AIR-CONDITIONING PURPOSES

The cooling equipment usually consists of refrigeration coils; these coils are maintained at temperatures of 40 to 50 F. and the air to be conditioned is blown past them. Such coils constitute a considerable refrigeration load. Refrigerated coils serve as dehumidifiers

of the air circulating past them (if the humidity is high), since some of the air will be cooled below the dew point and the excess moisture will be condensed out on the coils. This leaves the conditioned air both cooler and with less moisture. However, the cooled air is at 100% relative humidity and the cooled air must be mixed with other air to reduce the total relative humidity and eliminate the damp feeling. Naturally, adequate drains must be provided to carry away the moisture condensed on the cooling coils. Some air-conditioning plants use ice for the cooling medium, particularly if cooling is only needed for a comparatively few days of the year. Cold water from streams or wells may also be used for the cooling coils. The water should be 50 F. or colder, however, to produce any dehumidification. Most air-conditioning installations use automatic mechanical or absorption refrigeration as the cooling means.



25-16. A dehumidifier installed in a basement. It reduces the relative humidtiy at small cost. (International Harvester Co.)

25-10. AIR CLEANING AND FILTERING EQUIPMENT

This equipment usually consists of dry or moist filters of fibrous material through which the air is forced; the fibrous material removes most of the particles of dust and other harmful ingredients. Water sprays are often used to clean the air. These sprays may also serve to either humidify the air or dehumidify the air to some extent. In the winter water sprays, if they are kept fairly warm, will add considerable moisture to the dry air; in the summer if the spray water is kept cold it will tend to take moisture out of the air. Therefore, it serves to humidify, dehumidify, and clean.

Most air cleaning and filtering equipment must be cleaned periodically if it is to be efficient. See Chapter 23.

25-11. HUMIDIFYING AND DEHUMIDIFYING EQUIPMENT

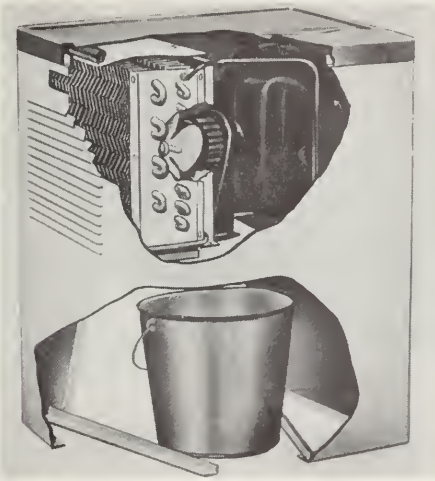
Humidifying equipment usually consists of a heated water surface over which conditioned air is forced to pass and moisture is picked up from the surface, depending upon the degree of humidifying required.

Dehumidifying equipment may consist of cold coil surfaces over which air is blown and the moisture is condensed out by coming in contact with the cold coils.

In some installations, certain chemicals are used which have the property of absorbing moisture from the air. In case chemicals are used, the chemicals are usually cycled in such a way that first the moisture from the air is absorbed into the chemical. Then the chemicals are heated, and the moisture is driven out-of-doors to put the chemicals in a condition to absorb moisture again.

A mechanism which performs a dehumidifying function is known as the dehumidifier, Fig. 25-16. This unit is usually a small hermetic refrigerating system that encloses in a cabinet both the condenser and cooling coil. The air is drawn over the cooling coil and after it is cooled below its dew point tem-

perature, the cooled air is moved over the condenser to reheat it to a reasonable relative humidity. The device is used to reduce the moisture content in air. It is useful in basements and other damp places, Fig. 25-17. A container



25-17. A phantom view of a dehumidifier. The first pass of the finned coil near the fan is the cooling and dehumidifying coil while the next pass is the condenser. Either a pail or a direct drain can be used to remove the condensate.
(International Harvester Co.)

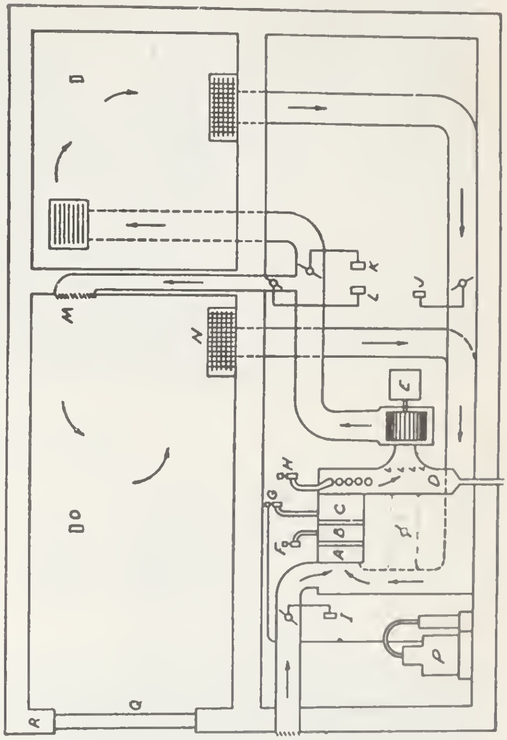
is used to collect the condensate. The condensate can also be drained directly to the building drains.

It should be remembered that most air-conditioning installations are engineering problems and that adequate calculations and specifications must be given; otherwise the system will not function satisfactorily.

The following represent some typical air-conditioning installations:

25-12. THE CENTRAL AIR-CONDITIONING PLANT

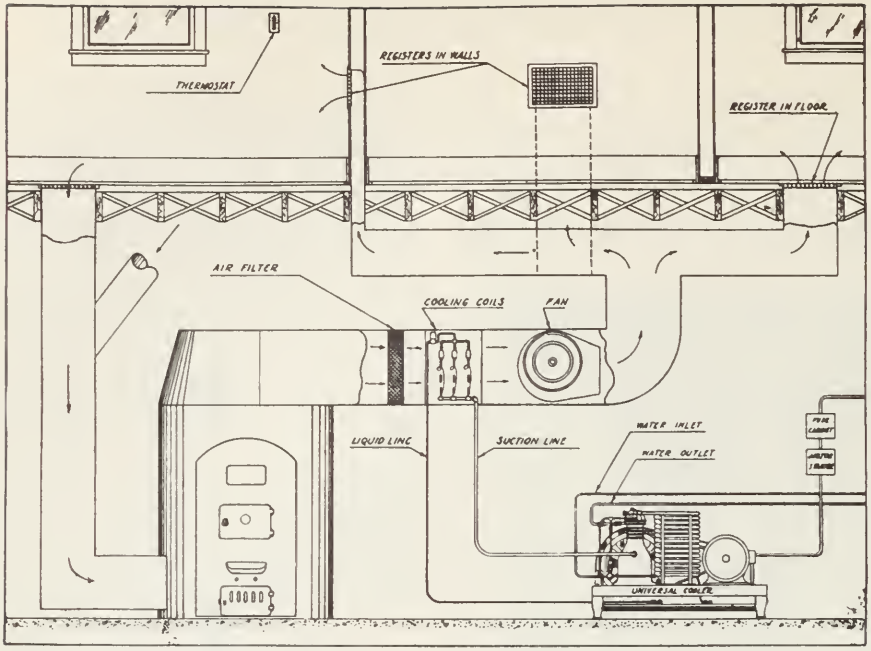
Fig. 25-18 illustrates a conventional duct air-conditioning system in which the entire plant is located in the basement and the conditioned air is circulated through ducts to the various rooms. Large plants of this type usually generate steam in a heating plant which circulates through coils in the air-conditioner for heating purposes. Small plants such as those used in small and medium size homes may be of the direct heating type in which heating of the air



25-18. A typical central or duct air conditioning plant. A. Filter; B. Heating coil; C. Cooling coil; D. Eliminator plates and moisture drain; E. Centrifugal fan and motor; F. Heatcontrol and shut-off; G. Refrigerant control and shut-off; H. Water spray control and shut-off; I. Fresh air control; J. Return air control and damper; K. and L. Conditioned air dampers and controls; M. Conditioned air inlet; N. Return air register; O. Room control; P. Refrigerating unit; Q. Double window; R. Insulated wall; S. By-pass and control.

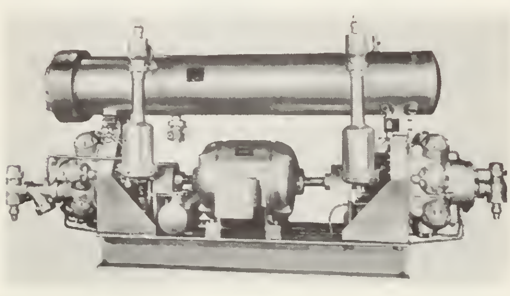
is accomplished directly from the furnace. In this case, accurate control of the furnace fire is necessary. The refrigeration plant for summer cooling usually uses a water-cooled condensing unit. These coils also dehumidify the air, and provision is made to drain away the moisture condensed from the air.

In Fig. 25-18 the ideal system is simply illustrated. Note that there is a



25-19. A typical direct heating duct installation for a small home.

fresh air intake to the conditioning apparatus. The filters (A) should have a large cross section to reduce air speed through them to a minimum. These filters may be the fibrous type, or they may be of the electrostatic type. To



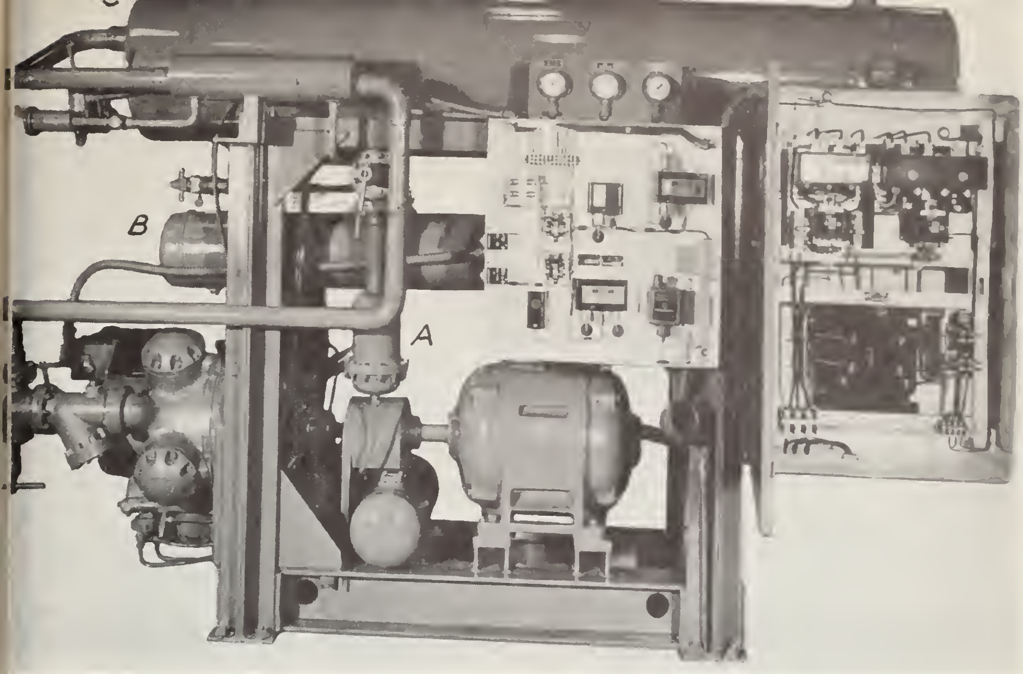
25-20. A 14-cylinder Central Station Unit installation. (Airtemp Div., Chrysler Corp.)

provide an exact control of the air being delivered to the rooms a by-pass is installed at (5) and the butterfly valve enables one to proportion the conditioned air to the by-passed air to obtain the correct temperature and humidity of the air being delivered to the rooms.

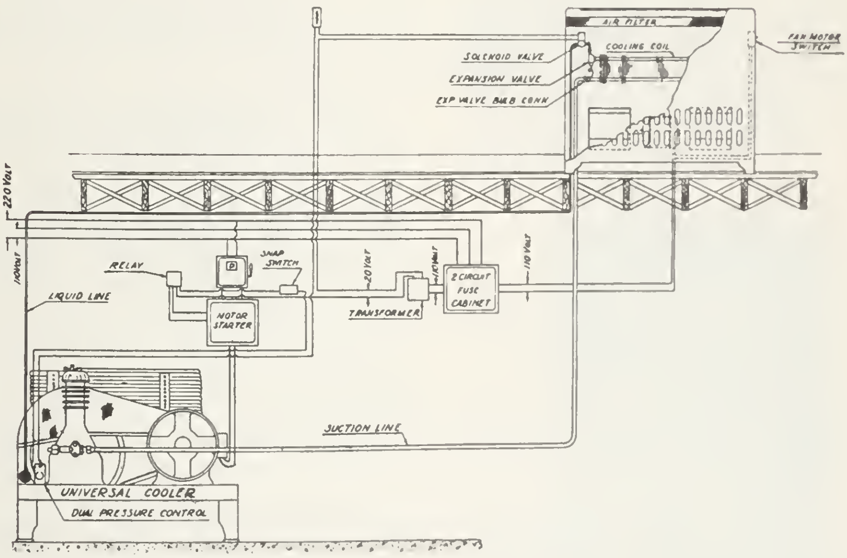
Fig. 25-19 illustrates a duct system used in a small home in which direct air heating is employed. A hand-fired coal furnace is used for heating and a refrigerating unit has been installed in the duct system to provide summer cooling. The filter and fan have been installed in the hot air duct. Most installations install the fan and filter unit on the inlet to the system. The condensing unit is a conventional unit with a water-cooled condenser.

Central station comfort cooling stations are available in a great number of styles. Fig. 25-20 shows a condensing unit for a large installation. It uses one motor to drive two separate compressors. Each compressor has seven cylinders. A shell and tube water-cooled condenser is mounted on top. This is a 75 H.P. unit that runs at either 1150 or 1750 r.p.m. This unit has a variable capacity system operated by unloading cylinders when the load decreases. Hydraulic controls unload the compressor to minimize the starting load.

Another air conditioning system circulates chilled water to the various cooling coils in the multiple installation. This chilled water system is also



25-21. A water chiller refrigerating mechanism. A. Oil separator; B. Receiver; C. Water cooling coil. (Airtemp Div., Chrysler Corp.)



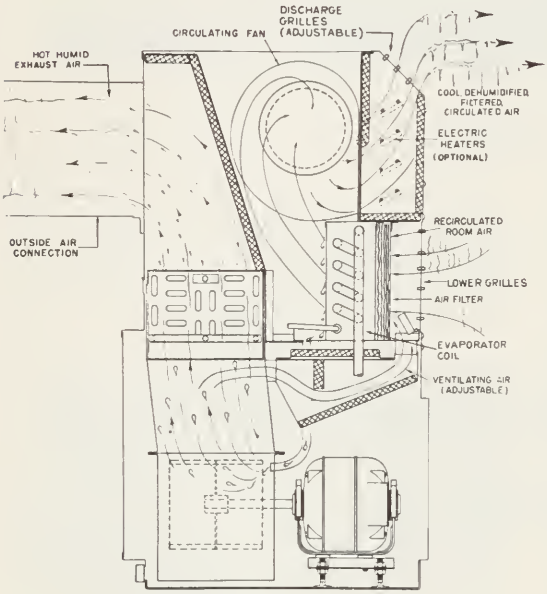
25-22. A remote air-conditioned plant.

used for many industrial processing installations. The unit is shown in Fig. 25-21. A direct drive five cylinder radial compressor is used. The compressor discharge gas goes through the oil separator (A) into the shell and tube condenser (B) to the water cooler (C) after passing through the heat exchanger. The large pipe on the left is the suction line. The three gauges shown are the suction pressure, the oil pressure and the high pressure gauges. The

two electrical control boxes contain the basic control on the left and the controllers on the right.

25-13. REMOTE COMFORT COOLING PLANT

The remote air-conditioning plant provides a refrigerating plant in the basement. The heating and refrigeration lines are then run to air-conditioning units in each room to be air-conditioned. Fig. 25-22 illustrates a remote air-conditioning plant. Such an installation operates with a pressure



25-23. A sectional view of an air cooled console model comfort cooler.
(Remington Air Conditioning, Div. of Remington Corp.)

motor control on the condensing unit. Individual thermostats are connected in each room to each air-conditioning room unit. A solenoid valve controls the refrigerant flow to the unit.

This valve is connected to the room temperature control, which controls both a fan and the solenoid refrigerant valve in the room unit in such a manner that liquid refrigerant to the room unit is turned on when the fan starts in the unit and is shut off when the fan stops. Some units use a thermostat to control the refrigerant solenoid valve only, while the fan runs continuously. Note that the thermostat circuit is 20 volts and the fan motor and compressor motor are 110-volt circuits. A thermostatic expansion valve refrigerant control is usually used. In large installations, multiple coils and several expansion valves are used.

Since the cooling coils are located in the room which is being air-conditioned, provision must be made to dispose of the moisture condensed out of the air in the summer. This is usually accomplished by connecting the unit to an open water drain by means of $\frac{1}{2}$-inch copper pipe.

Air filters must be provided in these units.

25-14. UNIT COMFORT COOLERS

Unit air-conditioners are of two types: (1) one type provides only comfort cooling for summer; (2) the other type provides both summer cooling and winter heating. Both types have a complete refrigeration plant included, i.e., condensing unit, refrigerant valves, and cooling coils. Individual room thermostats control the units. Filtering equipment is also a part of the system.

The console models may have either water-cooled or air-cooled condensing units. Air-cooled models are gaining in popularity due to water restrictions. Fig. 25-23 shows an air-cooled console unit. Note how the condensate from the cooling coil is entrained in the condenser air. Two separate motors drive the radial flow fans. Fresh air or ventilating air is by-passed from the air just as it leaves the condenser fan.

Some of the console models have a complete refrigerating system, a fil-

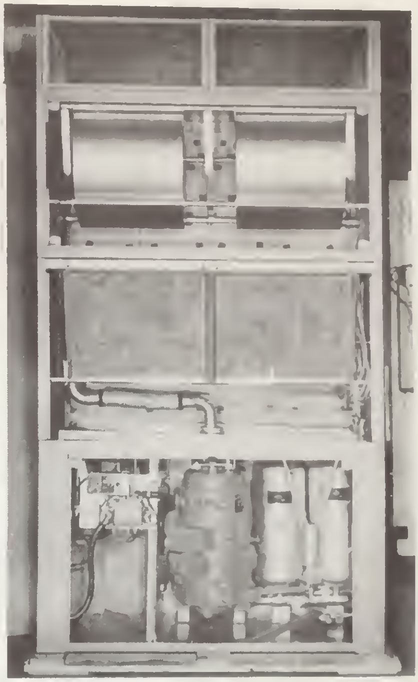
tering system and a cooling coil. See Fig. 25-24.

This unit is a large self-contained comfort cooler with provisions to add a heating coil if the user desires. This unit is of eleven (11) tons capacity. The inner construction is shown in Fig. 25-25. The thermostatic expansion

25-24. A self-contained console type comfort cooling air conditioner. The air intake is in the middle and the conditioned air is discharged out the top grilles. (Airtemp Div., Chrysler Corp.)

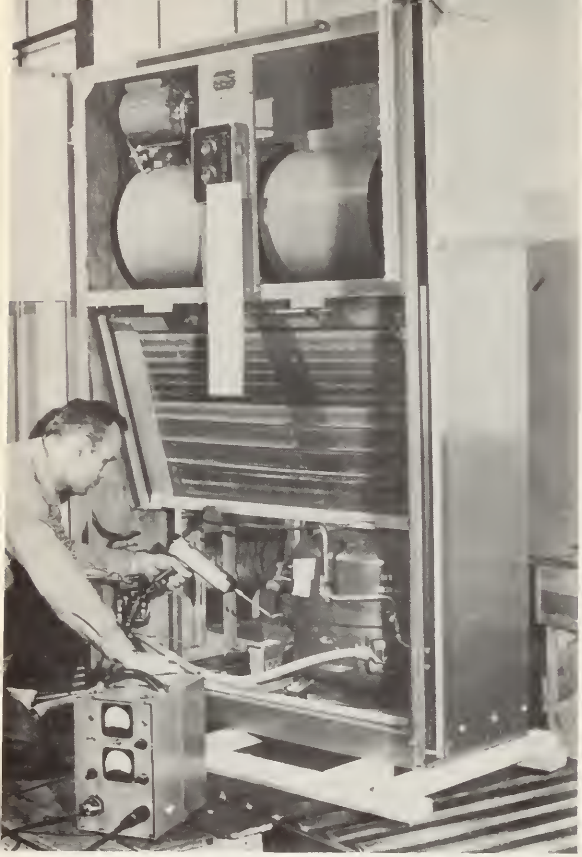
valves are of the distributor tube type. Note the equalizer tube connections to the suction line just to the right of the flexible pipe. The condenser consists of two vertical shell and tube water cooled units.

The details of the motor compressor are shown in Fig. 25-26. This unit is of two or three tons capacity. The four radial cylinders are located at the bottom of the unit and the motor is at the top. The suction line is fastened to the top center and the compressor discharge is located at the four bolt opening at the lower right. The glass sight port at the bottom is used to check the oil level. The condenser is either water-cooled or air-cooled. If air-cooled, a duct is used to bring in outside air and to discharge this air outdoors again. See Fig. 25-27.

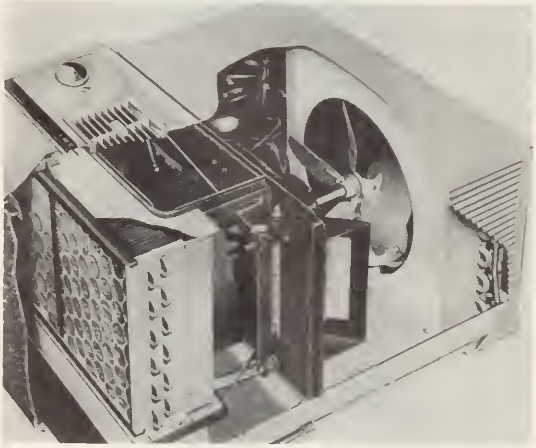


25-25. An air conditioning unit with front panels removed. Condensing unit, five cylinder hermetic compressor, water cooled condenser and fan motor are located in base. Cooling coils are mounted in back of filters and double radial flow fans are located at top. A steam coil can be mounted just below blowers if heating is desired. (Airtemp Div., Chrysler Corp.)

25-26. A motor-compressor hermetic unit for 2 and 3 ton packaged comfort cooling systems. (Airtemp Div., Chrysler Corp.)



25-27. A console type air conditioner being assembled. It is being checked for leaks with an electronic leak detector.
(General Electric Co.)



25-28. A window type comfort-cooling unit.
(International Harvester Co.)

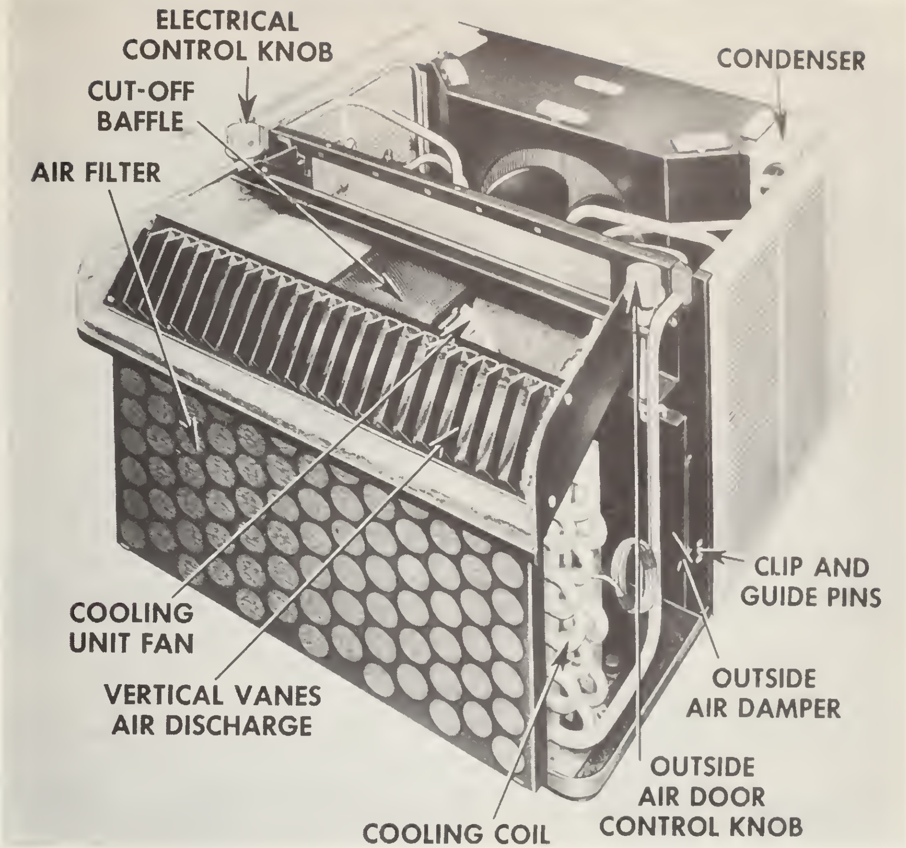
The water-cooled units require plumbing connections to both fresh water and a drain. The drain is also used to take care of the moisture condensed out of the air by the cooling coil in the summer. One company has developed a special three-flue rubber hose for this purpose which permits moving the unit quickly from room to room. Such a unit does not usually provide winter conditioning facilities.

Another popular type is the window mounted, or wall mounted comfort cooler. This unit mounts on a window sill for ease of installation. Fig. 25-28. Such units are of the 1/3, 1/2, 3/4 and 1 ton capacity. The condenser is located in that part of the cabinet that extends outside the building. Outside air is forced over the coil by a fan. Inside the room another fan draws air in through a fibrous filter and forces it over the cooling coil. The two radial flow fans are usually driven by the same motor.

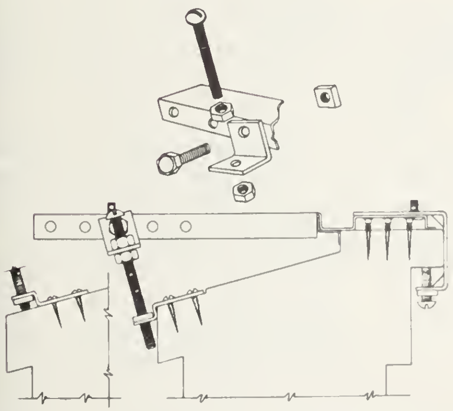
A window unit that uses two separate compressors for variable capacity purposes is shown in Fig. 25-29.

Window units are available in several models. One model cools the air, filters the air, and has a fresh air intake. Another model has these same devices but in addition has an electrical resistance heating unit to furnish heat for fringe temperature conditions. Still a third type uses a reverse cycle system to permit the use of the refrigerating units as a comfort cooling unit and a heating unit.

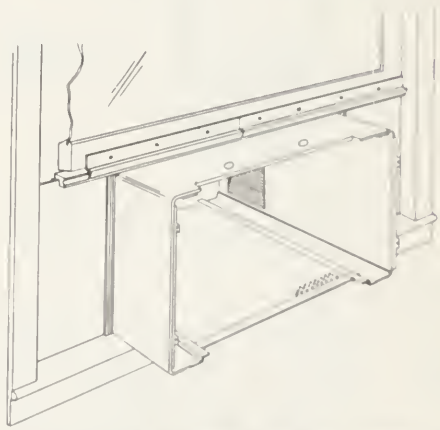
The units are installed in windows. Metal plates, rubber gaskets, and sealing compounds are used to seal the unit into the window. Fig. 25-30 shows a window sill. After the sill brackets are installed, and the unit housing installed, the rubber seal strips and the filler boards are installed. Fig. 25-31. The mechanism can now be installed inside the cabinet and the front fixtures mounted.



25-29. A two rotary compressor window air conditioning unit.
(Frigidaire Div., General Motors Corp.)



25-30. The bracing used to hold a window air conditioner on a sill.
(Remington Air Conditioning, Div. Remington Corp.)



25-31. A window air conditioner being installed with the rubber seal strips and the filler boards installed.
(Remington Air Conditioning, Div. Remington Corp.)

Window units can be obtained to fit double hung windows, casement windows, or can be installed in special wall openings.

The condensate from the cooling coil is drained to the base of the motor-

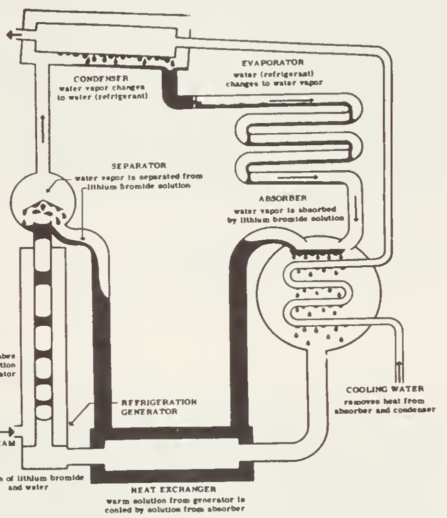
compressor and the condenser where its evaporation helps to cool these parts. A capillary tube refrigerant control is usually used.

A valve mechanism enables the cycle to be reversed and the same unit can be used to heat the room. See Chapter 26.

25-15. ABSORPTION SYSTEMS

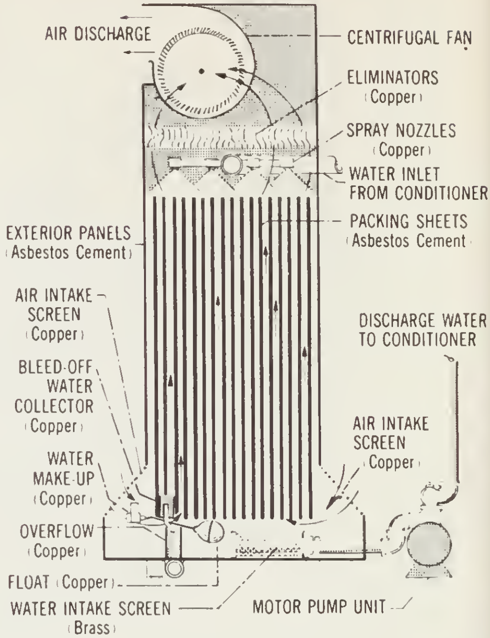
Absorption systems are being successfully used for air conditioning comfort cooling installations. The systems naturally lead to heating also. Fig. 25-32.

The system uses water as the refrigerant and lithium bromide as the



25-32. An absorption refrigeration cycle that uses water as a refrigerant and lithium bromide as the absorbent. (Servel Inc.)

absorber. Steam heat applied to the generator percolates water vapor and weak solution up to the separator. The liquid lithium bromide (black) then flows by gravity through the heat exchanger to the absorber where the lithium bromide absorbs the evaporated water and the strong solution settles to the bottom of the absorber, and then returns to the generator after passing through the heat exchanger (the black

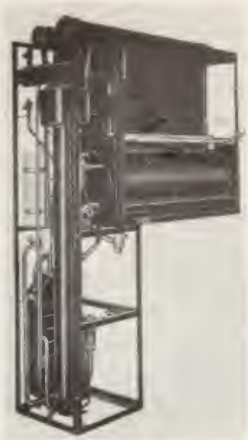


25-33. A cooling tower used to cool condenser and absorber cooling water. The tower evaporates about 15 per cent of the condenser water and in so doing cools the rest of the water down to the wet bulb temperature of the air. It consists of water sprays, asbestos sheets, overflow tubes, make up water float valve, water pump. Eliminator plates keep water from being drawn into the fan. Air enters at the bottom and leaves at the top. (Servel Inc.)

is warm and the gray is cool). The pressure difference is maintained by the pressure head of the lithium bromide liquid.

The hot steam in the separator rises up the condenser where it is condensed and turned into water. The condensed water (black) flows by gravity through an orifice, into the cooling coil or evaporator. The water evaporates at a low temperature due to the almost perfect vacuum and the steam (water vapor) formed is then absorbed by the lithium bromide. Note that the absorber and the condenser are both cooled by water coils. The condenser water is then taken to a cooling tower where it is cooled, Fig. 25-33.

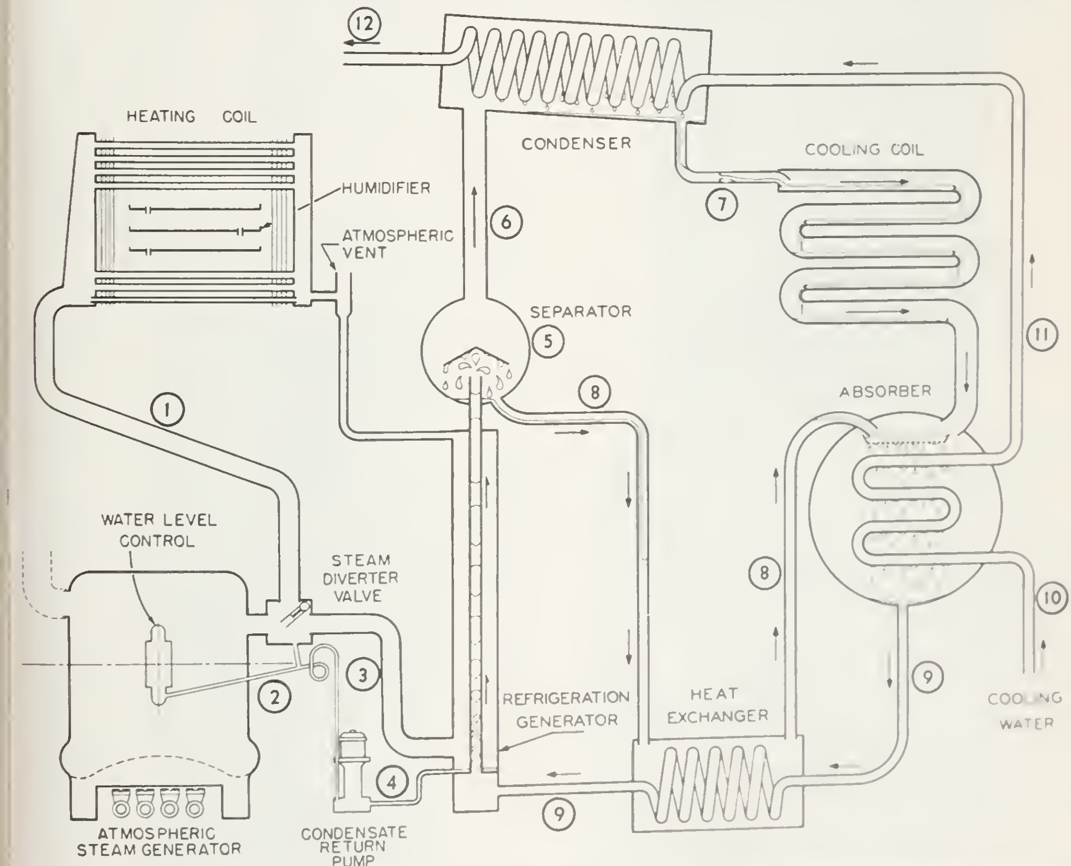
The actual machine is shown in Fig. 25-34. The condensing pressure is about 50 to 60 millimeters of Hg (about



25-34. The cooling system mechanism used in Servel comfort cooling absorption machine. Air to be cooled and dehumidified is passed through finned cooling coil in upper right of picture.
(Servel Inc.)

3 psia) and the evaporating pressure is 8 to 10 millimeters of Hg (about .5 psia). The large cylinder in the middle right is the absorber. The cooling coil is the finned section in the upper right. The long vertical cylinder is the generator and its large upper section is the separator. The two horizontal cylinders at the extreme top are condensers.

A year round Servel air-conditioner (both heating and cooling) is shown in Fig. 25-35. The heating section is on the left and the cooling mechanism is on the right (1) steam line to heating coil, (2) steam condensate return pipe, (3) steam line to generator, (4) steam condensate return line from generator, (5) separator, (6) pipe to condenser, (7) reducing orifice, (8) pipe feeding



25-35. Cycle of a Servel year-round air conditioner. Steam is used for heating section and to heat the generator of the cooling system.
(Servel Inc.)

lithium bromide to absorber (9) return pipe from absorber, (10) condenser water into system, (11) condenser water pipe from absorber to condenser, and (12) condenser water to cooling tower.

These systems are also used to produce chilled water. The chilled water in turn is used for a multitude of processes such as quenching baths, drinking water, cooling welding tips, etc.

25-16. AIR-CONDITIONING CONTROLS

The chief value of complete air-conditioning lies in its accurate automatic operation. This necessitates many controls. These controls include controls such as:

1. Heating Controls
   (a) Coal heat
   (b) Oil heat
   (c) Gas heat
   (d) Steam controls
   (e) Water controls
   (f) Limit controls
2. Cooling Controls
3. Humidifying Controls
4. Dehumidifying Controls
5. Air Flow Controls

25-17. TEMPERATURE CONTROLS

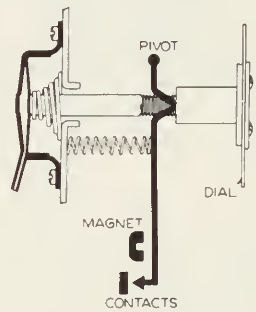
Temperature controls used on air-conditioning plants vary somewhat from the type used on refrigeration installations. Several different types of controls are used.

These thermostats usually operate on a 1 F. to 2 F. differential, which results in close temperature control.

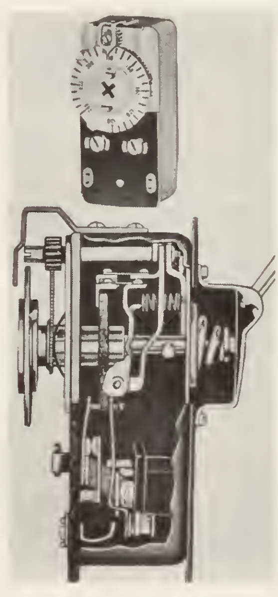
The sensitive element is usually a bi-metal strip. A small magnet is used to produce snap action of the points. A range adjustment is usually a direct load on the bi-metal while the differential usually consists of moving the small magnet either closer or farther away from the bi-metal strip.

Some thermostats are hydraulically operated. Fig. 25-36 shows a diaphragm mechanism with the diaphragm movement caused by expansion and contraction of a liquid. Note the adjustment and the small magnet used to obtain snap action. The actual thermostat is shown in Fig. 25-37.

Thermostats are rated by the voltage they carry and also by the controls to which they are electrically connected. Some thermostats have a time clock mechanism which will change the ther-



25-36. A schematic diagram of a hydraulically operated thermostat.
(White-Rodgers Electric Co.)



25-37. An external and internal view of a hydraulic type thermostat.
(White-Rodgers Electric Co.)

mostat setting automatically at certain set time intervals. One example is using a clock for obtaining lower night temperatures, and normal day temperatures.

Other thermostats use hydraulic pressure to actuate the switch.

25-18. HEATING THERMOSTATS

The types of heating thermostats which have been most used in domestic service are the series 10, the series 20, the series 80 etc.

The series 10 thermostat has been very popular but is now being replaced by a high voltage thermostat, series 80. The series 10 is a 24 volt unit and has three wires. The three wires are used to make a contact on temperature drop and then to close a holding circuit. This thermostat must be used with a relay. The relay contacts control the 110 V. circuit for the oil burner, gas burner, or stoker.

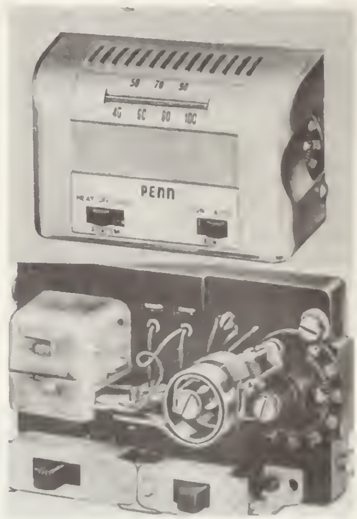
The series 20 thermostat is also low voltage but it is a two wire system used with low voltage controls and may be used on gas burners, oil burners, or stokers.

The series 80 thermostat is a two wire 110 V. thermostat that controls the furnace devices directly.

An interesting problem in room heating thermostats is brought about by the fact temperature always tends to rise above the thermostat setting after the thermostat points have opened and the burner stopped. This action is the result of the residual heat in the furnace. To correct this overheating, the manufacturers have placed small heating coils in thermostats. Therefore, during the heating cycle, the thermostat is always about 1 F. warmer than the room. If the thermostat is set for 74 F. the thermostat will open when the room temperature is actually 73 F. Then the room temperature will rise to 74 F. because of the heat in the already heated furnace. These small resistance coils are usually called anticipator coils.

For heating purposes the thermostat is designed to close the contacts when cooled while the thermostat used for cooling control closes the contacts when the temperature rises.

The thermostats must be located carefully. They must not be exposed to drafts, to hot or cold walls, to sunlight, etc. They must be located in an average temperature location. An inner wall is the most popular place. The thermostats are mounted about five feet above the floor. If placed closer to the floor the temperature control will be more uniform however it is more likely to be disturbed by children or furniture. These thermostats should be kept as clean as possible inside.



25-38. A combination heating and cooling thermostat. (Penn Controls Inc.)

If lint should lodge between the points, an open circuit will result.

25-19. COOLING THERMOSTATS

Comfort cooling thermostats are similar in design to heating thermostats except that the contacts open as

the room cools and close as the room warms up.

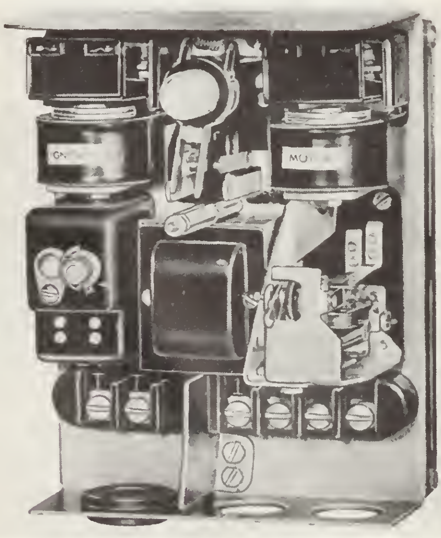
25-20. COMBINATION THERMOSTATS

Some thermostats have both heating control and cooling control mechanisms. A simple snap switch is used to change from one cycle to the other, Fig. 25-38.

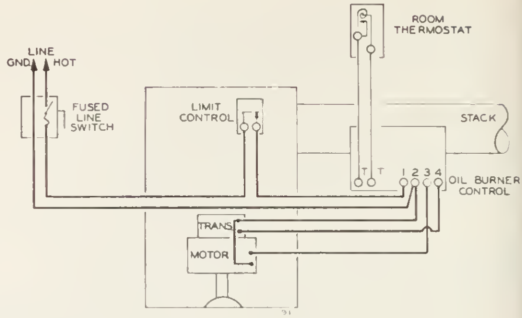
25-21. FURNACE CONTROLS

All thermostats send an electrical signal to other electrical devices such as solenoid valves, relays, magnetic starters, etc.

One such control is shown in Fig. 25-39. It is commonly known as an oil burner primary control. It mounts on the furnace stack and responds to the thermostat and to a bi-metal strip suspended in the stack. The control operates the burner motor and also the ignition. However, if the oil does not ignite and if therefore the stack does not heat in a very few brief seconds, the safety bi-metal will shut off the



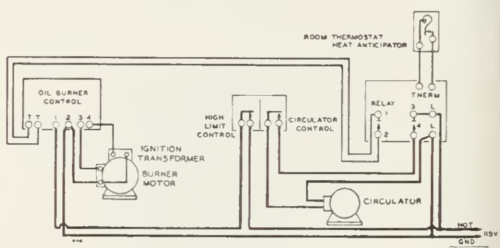
25-39. An oil burner primary control, which will cycle the oil burner, operate the ignition system, shut off the unit if ignition fails, scavenge the unit on each cycle, etc. (White-Rodgers Electric Co.)



25-40. A wiring diagram for a gun-type oil burner. (White-Rodgers Electric Co.)

current to the motor and ignition. The unit must be manually reset before it will operate. The control shown has a wiring diagram as illustrated in Fig. 25-40. Note the series connection between the power, the limit control and the primary control. The thermostat wires are low voltage while the others are 110 volts.

Oil burners, gas burners and stokers all have their own distinctive



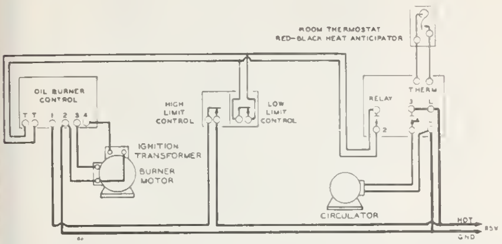
25-41. A wiring diagram of a gun type oil burner installation with a circulator motor control. (White-Rodgers Electric Co.)

electrical components and wiring diagrams. Fig. 25-41 shows the wiring diagram of a gun-type oil burner installation with a circulator motor. The heavy wires are high voltage (115 V.) lines and the light wires are 24 volt lines. Note that the circulator control has its own separate control.

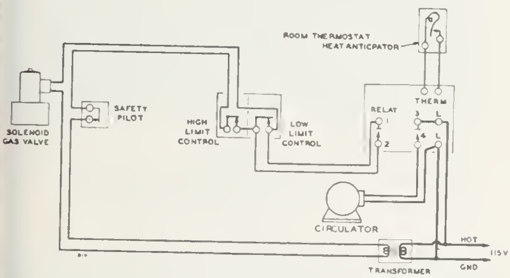
A slightly different wiring diagram of a gun type oil burner installation is shown in Fig. 25-42. This system

operates the circulator motor when the room thermostat calls for heat.

Gas furnaces use many varieties of electrical devices. Some operate on 115 volts, some on 24 volts and some



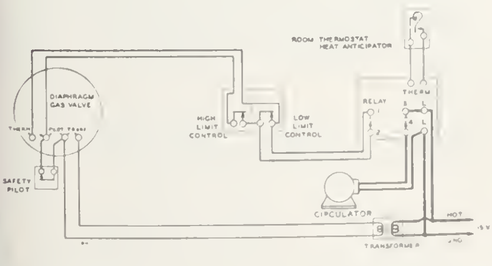
25-42. A gun type oil burner installation with a circulator wired to run at all times the burner is operating. (White-Rodgers Electric Co.)



25-43. A solenoid operated gas line valve; low voltage type. Note the transformer in the lower right corner. (White-Rodgers Electric Co.)

on current generated by a thermocouple (25 to 700 millivolts).

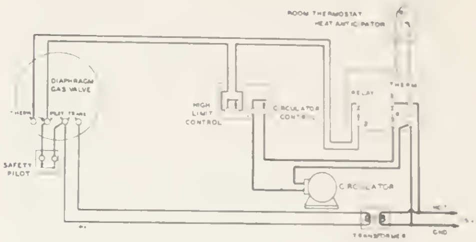
A wiring diagram of a solenoid operated gas line valve is shown in Fig. 25-43. It is a low voltage valve



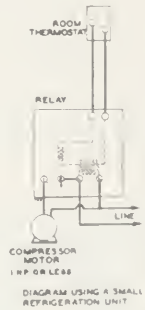
25-44. Wiring diagram of a diaphragm-type valve heating plant. (White-Rodgers Electric Co.)

and it has a safety pilot, controls and the relay in series with it. The thermostat is a series 20 thermostat (2 wire, low voltage).

A diaphragm type gas valve wiring diagram is shown in Fig. 25-44. It has a circulator motor that operates all



25-45. Wiring diagram of diaphragm-type gas valve heating plant. Note that heavy lines represent line voltages and lighter lines represent low voltages. (White-Rodgers Electric Co.)



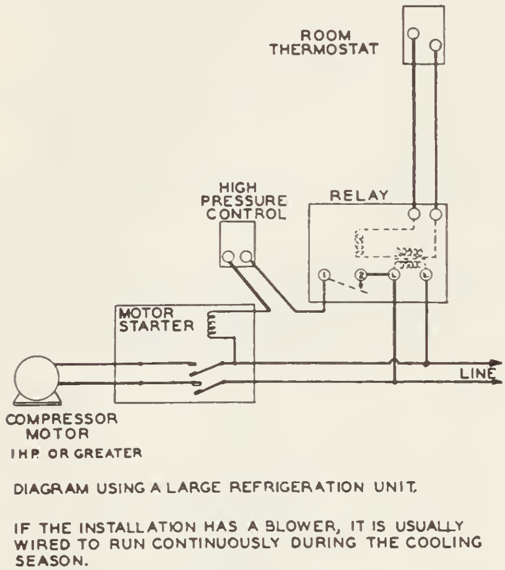
25-46. Wiring diagram of thermostat, relay combination for small comfort cooling units. (White-Rodgers Electric Co.)

the time the burner is operating. Fig. 25-46 shows a circulator motor that is controlled by its own temperature control.

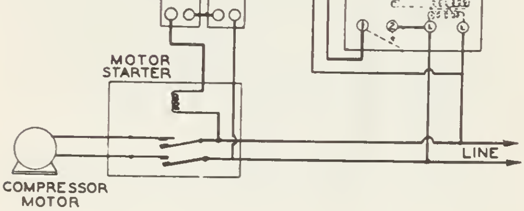
25-22. COMFORT COOLING CONTROLS

The complete wiring of a comfort cooling unit is shown in Fig. 25-46. This system uses a two wire thermostat, low voltage. The thermostat controls a relay which will close the motor circuit. If the motor cannot be

connected directly to the line and if pressure safety devices are to be put in the system, the wiring will be somewhat similar to that shown in Fig. 25-47. The high pressure safety cut-out is in series with the starter coil and it will open the circuit if the unit pressures become excessive.

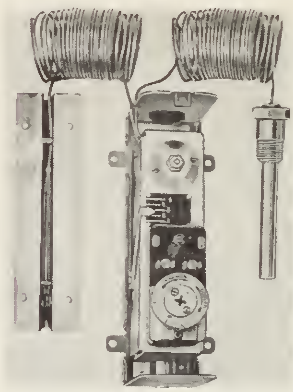


25-47. Wriing diagram of a comfort cooling unit which uses a high pressure safety cut-out and a motor starter. (White-Rodgers Electric Co.)



25-48. A comfort cooling coil wiring diagram. This system has the thermostat operate the solenoid valve. The system cycles as the low side pressures vary. (White-Rodgers Electric Co.)

Some units cycle on the basis of a low side pressure switch. The thermo-



25-49. A combination thermostat used in radiant heating installations. It has an outside sensitive bulb which adjusts the thermostat to higher water temperatures when the outside temperature lowers. (White-Rodgers Electric Co.)

stat operates a solenoid valve mounted in the liquid or suction line. When the thermostat is satisfied the solenoid valve will close and when the low side pressure drops enough, the motor circuit will be opened by means of the magnetic starter and the unit will stop, Fig. 25-48.

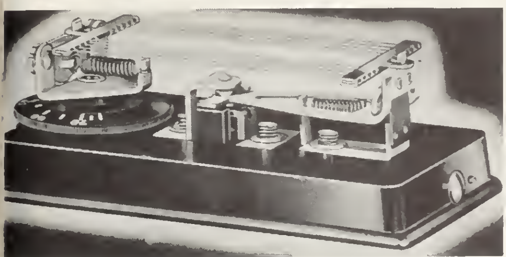
Many homes now use circulating hot water heating systems. This sytem is especially popular for radiant heated homes. To provide hotter water when the outside temperature drops, an inside-outside differential thermostat is used to provide a change in water temperature as the outside temperature changes, Fig. 25-49. It is important to install all electrical systems according to the National and Local Electrical Codes.

25-23. HUMIDITY CONTROLS

Humidity controls are important in keeping the relative humidity of the air-conditioned rooms satisfactory. Humidity controls operate during periods of winter heating to add moisture

to the air, and keep the humidity approximately constant.

Humidity controls operate in the summer to remove moisture from the air. For the removal of moisture the humidity control usually operates an air by-pass to put more air over the cooling coils. Such controls usually operate electrically to regulate solenoid valves or dampers. The control element may be either wood or human hair which are both sensitive to the amount of moisture in the air. Fig. 25-50 illustrates the interior construction of a

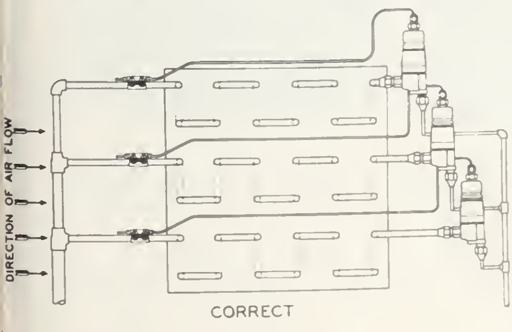


25-50. A humidity control showing the operating mechanism.

popular humidity control device. Health studies indicate that humidity control is a very important factor in air-conditioning.

25-24. REFRIGERANT CONTROLS

Large air-conditioning cooling coils

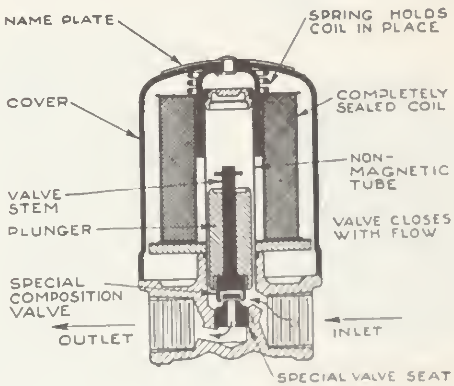


25-51. An air cooling coil showing the correct location and installation of three thermostatic expansion valves. (Detroit Controls Corp.)

usually use the thermostatic expansion valve refrigerant control. Some installations use several such expansion valves on one large coil in order to get the maximum efficiency from the coil, Fig. 25-51. Self-contained systems, especially the hermetically built ones may use the capillary tube refrigerant control.

In addition to the refrigerant control used on automatic refrigeration systems a solenoid refrigerant valve is usually placed in the liquid line. This automatically stops the flow of refrigerant to the coil the instant the condensing unit stops. It is necessary in order that the cooling coil will not become flooded with refrigerant while the condensing unit is idle. Fig. 25-52 illustrates a typical solenoid refrigerant control valve.

The refrigerating units are usually equipped with pressure controls. These low and high pressure controls are usually designed to lock the circuit open if any unusual pressures occur.

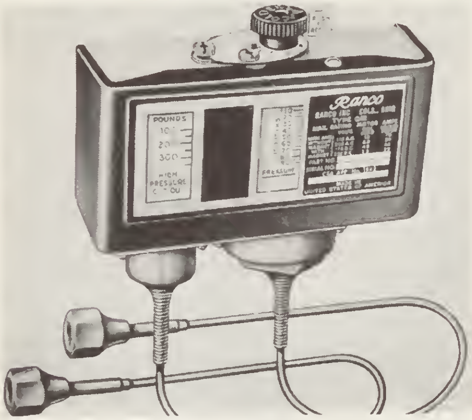


25-52. A cross section of a solenoid refrigerant control used on air conditioning coils. (A-P Controls Corp.)

The operator must manually turn the system on. This action insures careful checking of the unit for any fault. See Fig. 25-53 and Fig. 25-54.

25-25. AIR-CONDITIONING TIMERS

There are many air conditioning installations that can be automatically timed for operation. Air conditioners installed in offices need not run on



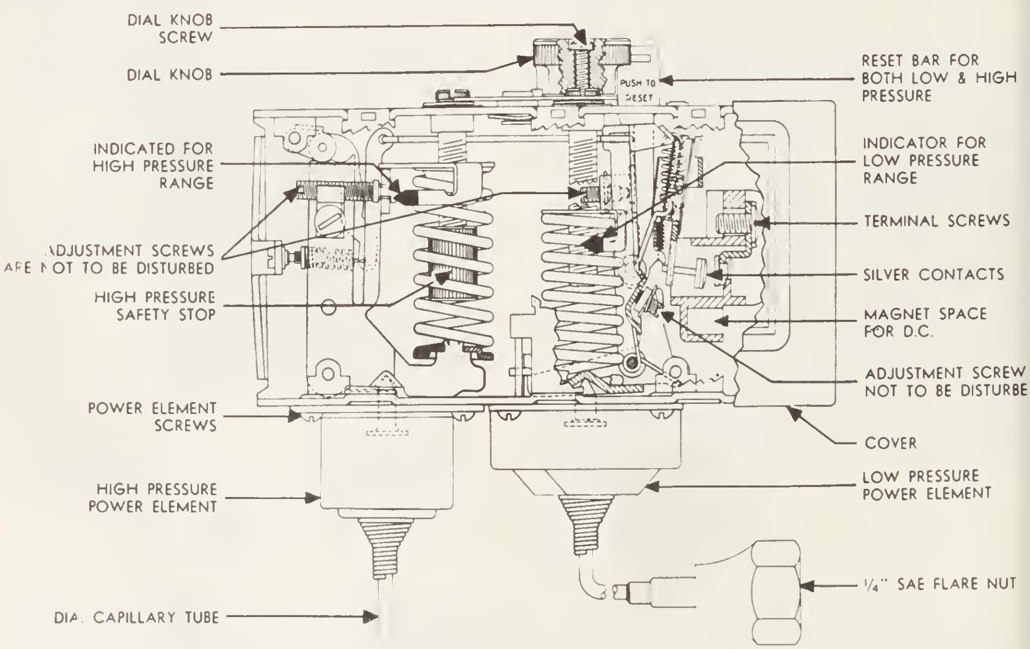
25-53. A dual pressure control for air conditioning condensing units. This control will stay open if excessive head pressure below normal low side pressures are encountered in the system. A manual reset is necessary and the trouble is therefore detected early.

25-55. A seven day automatic timer for controlling the air conditioners running time for every day in the week. (Paragon Electric Co.)

Saturdays or Sundays. Also they need not run during non-working hours.

Many users of air conditioners want the units to start functioning at a certain time before the premises are used.

Fig. 25-55 illustrates an automatic timer that operates on a seven (7) day schedule. The "buttons" on the peri-



25-54. The inner mechanism of an air conditional condensing unit pressure motor control. (Ranco Inc.)

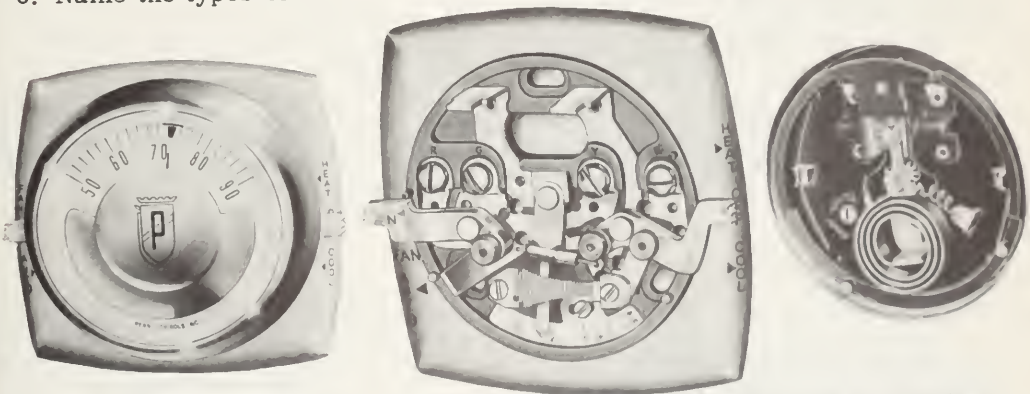
phery of the time disc can be set to turn on the air conditioner at any set time and shut it off at any set time each day. Note that Saturday afternoon and Sunday do not have off and on buttons. Therefore the unit will not run during this time.

25-26. REVIEW QUESTIONS

1. Name three types of air-conditioning plants.
2. What refrigerant controls are usually used on air-conditioning cooling coils?
3. Why are solenoid refrigerant control valves necessary on air-conditioning cooling coils?
4. What is the most economical way to use electricity for heating?
5. How does a by-pass air system operate?
6. List the four most common sources of energy for heating?
7. What is the heating value of bituminous coal?
8. Name the types of oil burners.
9. What is one advantage of gas as a fuel?
10. Why must stack temperatures be kept over 300 F.?
11. Why is air leaving a cooling coil considered to be damp air?
12. Can air be dehumidified by any other method than by cooling?
13. How is condensate handled in a unit comfort cooler?
14. What air is used to cool the condenser of an air cooled comfort cooler?
15. What is a bi-metal thermostat?

25-27. THERMOSTATS

A new style thermostat has recently (1959) been developed for air conditioning systems. These units have easily manipulated settings. They are designed with all the various types of electrical bases to enable the thermostat to control either 1 heating system, 2 cooling systems, or 3 combination heating and cooling systems. Fig. 25-56 illustrates one of these units.



25-56. An easily adjusted room thermostat. These new models are available for many types of applications. (Penn Controls, Inc.)

Chapter 26

HEAT PUMPS

All refrigeration units are heat pumps. They all move heat from one place to another. They all pick up heat at low temperature level and release it at high temperature level.

The cooling coils and condensers are both heat transfer devices and they could each be used for both cooling (picking up heat) or heating (releasing heat).

The principle of using the refrigeration unit as a heating mechanism too was first proposed by Lord Kelvin over 100 years ago but it has only been since World War II that there has been a serious effort to actually use the mechanism for heating.

The heat pump is also called a reverse-cycle mechanism. However, the cycle is not actually reversed, only the cooling coil and condenser are interchanged and therefore the name "reverse-cycle" is not technically correct.

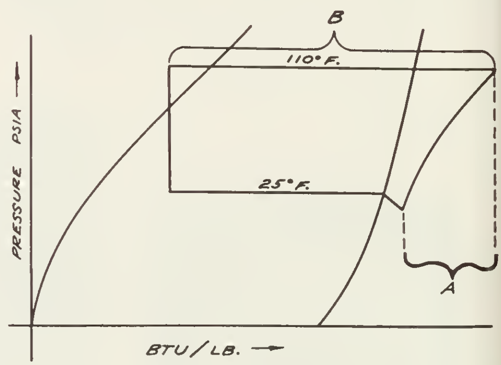
26-1. PURPOSE

The heat pump is a mechanism that can either remove heat from the occupied space and discharge this heat to the outside or it can be used to pick up heat from the outside and discharge it into the occupied space to heat it.

26-2. THEORY

The theory of the heat pump is that heat will move from a high temperature to a lower temperature. This principle means that if a heat transfer coil can be maintained at a lower temperature than its surroundings, it will pick up heat from its surroundings.

Therefore if the cooling coil of a refrigerating system can be kept at a temperature below its surroundings it will pick up heat. If a cooling coil is mounted outdoors and operated at a refrigerant temperature of 0 F., it will

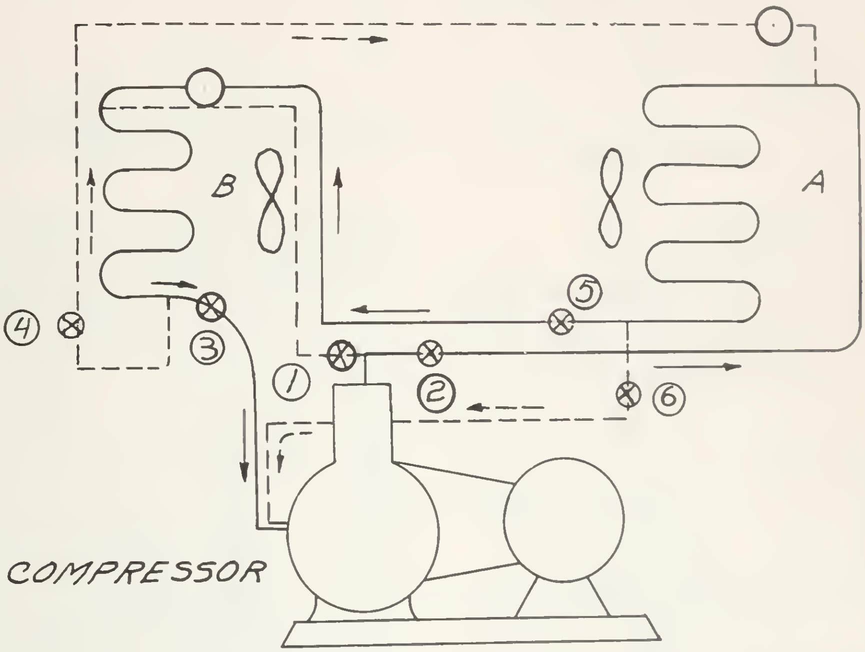


26-1. A typical heat pump cycle used for heating, with a refrigerant evaporating outside at 25 F. (35 F. air) and this same refrigerant condensing at 110 F. in a condenser in an air duct. A. Heat of compression; B. Heat released to the house.

remove heat from the air even though the outside temperature is 10 or 15 F. Now if this refrigerant after it has evaporated is compressed by a compressor to a temperature of 120 F. to 140 F. this hot refrigerant will release heat to the surroundings, i.e., the inside of the house. Then, if by using

a system of valves, the cooling coil is changed into the condenser and the condenser is changed into the cooling coil during the summer months, heat can be removed from the occupied zone and discharged or moved outdoors, Fig. 26-1.

However, there are two liquid lines, two suction lines, and two refrigerant controls used in the simpler of the heat pumps in order to change from summer cooling to winter heating, Fig. 26-2. Now if coil A is mounted inside the house in an air duct, it



26-2. A heat pump. Both heat transfer coils are blower coils. The solid refrigerant lines are used when values 2, 5 and 3 are open while values 1, 4 and 6 are closed. Coil A is then the condenser and B the cooling coil. By closing values 2, 5 and 3 and opening 1, 4 and 6 the refrigerant will flow through the lines shown dotted, and A will become the cooling coil while B will become the condenser.

can either be used to give up heat to the house or it can be used to remove heat and moisture from the house.

The system can be simplified to three two-way valves by combining (4), (3), (1) and (2), (5), (6).

Further careful design has produced one four-way valve to reverse the flow of refrigerant. Some of these valves are electrically operated to permit changing the system over by simply pushing a button.

Many systems use a compact unit containing the refrigerant. The system

26-3. OPERATION

The operation of the heat pump is identical to any compression cycle. The principal parts of the system are:

1. Compressor
2. Condenser
3. Receiver
4. Liquid Line
5. Refrigerant Control
6. Cooling Coil
7. Suction Line
8. Motor Control

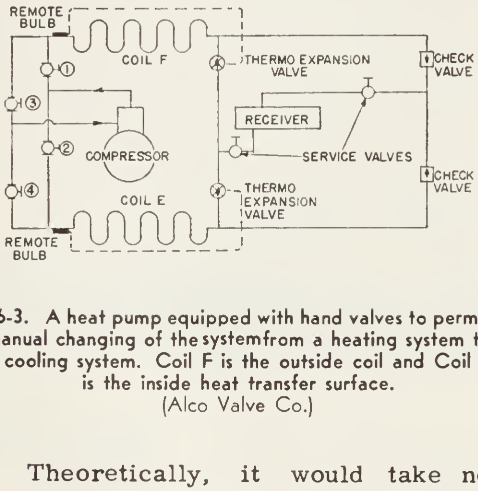
has its heat transfer surfaces self-contained in this unit. The heat transfer units in this system cool or heat liquids and these liquids in turn are pumped through heat transfer surfaces either outdoors or indoors. This system requires two liquid pumps but it enables the heat pump to operate more efficiently and confines the refrigerant to a relatively small space.

26-4. CYCLES

The heat pump actually operates as two cycles:

1. Heating cycle
2. Cooling cycle

The same mechanism is used for both cycles but the travel of refrigerant is reversed in order to change from cooling to heating, Fig. 26-3.



26-3. A heat pump equipped with hand valves to permit manual changing of the system from a heating system to a cooling system. Coil F is the outside coil and Coil E is the inside heat transfer surface.
(Alco Valve Co.)

Theoretically, it would take no energy to maintain correct conditions if the outside (ambient) temperatures equalled inside temperatures.

For example:

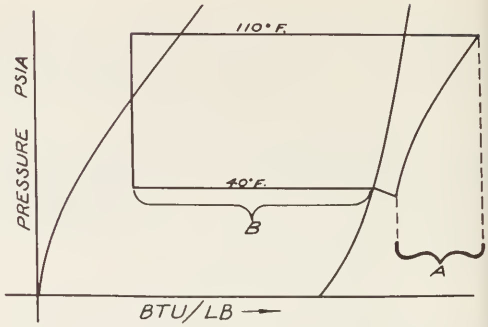
Outside (ambient)

Temperature F	Humidity %
72	50

Inside

Temperature F	Humidity %
72	50

If the ambient conditions are within 10 F. and 10% of these conditions,



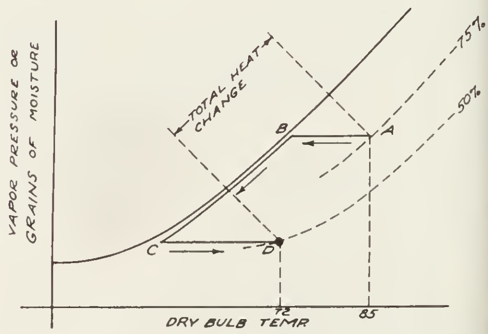
26-4. A cooling cycle for a heat pump. A. Heat energy of compression; B. Heat energy removed from the air (cooling and dehumidifying). Note that A is approximately one-third of B.

very little treatment is needed due to the heat lag and time lag in controlling the variables. But if the ambient temperatures were to increase over this amount, for example:

Outside (ambient)		Inside	
F	%	F	%
85	75	72	50

The cycle would be as shown in Fig. 26-4.

On the psychrometric chart, the apparatus would affect the air conditions as shown in Fig. 26-5. Point A is the condition of the ambient air and the line A to B cools the air to 100% humidity and the line B to C is cooling the air and also removing moisture from the air. If 100% fresh air is being conditioned, point C represents the air as it leaves the cooling coil.



26-5. The effect on the air in a house when using the cooling cycle of a heat pump.

Then as the air mixes with the air in the house or with air being brought into the duct system (recirculated air) point D is reached.

The heating cycle consists of removing heat from the ambient air and releasing this heat in the house. It must be remembered that heating is not usually needed until the outdoor temperature is less than 65 F. Heat from appliances, and occupants usually makes up this small difference.

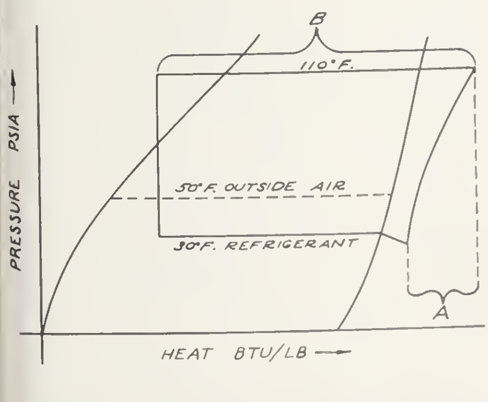
For example, if the following conditions prevail

Outdoor	Inside
50 F. 80%	72 F. 50%

the outdoors coil will operate as a cooling coil and pick up heat from outdoors and discharge this heat into the house, Fig. 26-6.

The heating cycle of the heat pump becomes less efficient as the outdoor temperature lowers. This action plus an increase in the load as the outside temperature lowers offers considerable difficulties for those latitudes where temperatures drop to 20 F. down to 0 F. outside, Fig. 26-7.

Note that A has increased with very little increase in B which means that the coefficient of performance is less. Also with the refrigerant boiling at 0 F., the cooling coil will frost rapidly necessitating some frequent defrosting means.

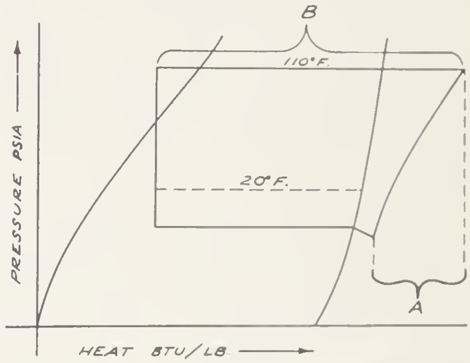


26-6. A heat pump serving as a heating system with the outside temperature at 50 F., the refrigerant evaporating at 30 F. and the refrigerant condensing at 110 F. The ratio of A to B is the co-efficient of performance (cop).

26-5. PERFORMANCE

The heat pump can be built to fit any need. The units have been designed for single rooms, for complete houses, and for industrial uses. The unit takes the place of both the comfort cooling unit and the heating apparatus.

The source of energy is electricity. To furnish 50,000 Btu's per hour directly from electricity requires (@ 1 kwhr. = 3410 Btu/hr). 50,000 Btu/hr. ÷ 3410 Btu/hr. = 14.6 kwhr.



26-7. A heat pump heating cycle in operation when the outside (ambient) temperature is 20 F.

At 1 cent per kwhr., the heat load would cost 14.6 x .01 = .146/hr. = .146 x 24 = $3.50/day. For one 30 day month the cost would be $3.50 x 30 = $105/mo.

Obviously, this cost is prohibitive, but actually the cost is much less than this as the heat load of a house averages much less than this value. Based on a degree day basis and assuming 10,000 degree days per season for the area in the problem (avg. 35 F. ambient temperature over a 9 month period). The heat load for a 50,000 Btu/hr./70 F. temperature difference house the Btu loss per hr. per temperature degree will be $\frac{50000}{70} = 714$

Btu/degree F/hr. The heat load for 24 hrs. 714 x 24 - 17,136 Btu/degree day
17,136 = 502 kwhr./degree day.
5.02 x .01 x 10,000 = $673.00/ season cost for heating by electrical resistance.

The heat pump reduces this cost considerably.

The heat pump uses electricity only to drive the compressor. The refrigeration cycle, if the proper temperatures are used, permits the condenser to release three to four times as much heat as it takes in electrical energy to drive the compressor. This coefficient of performance (c.o.p.) means that one kwhr. of electrical energy driving the compressor can, by using the heat pump, release not 3410 Btu/hr. but 3410 x 3 or 10,230.0 Btu/hr.

This coefficient of performance can be further increased by using some warmer heat source than the outside air. For example, well water, lake water, and the very ground itself, has been used to provide the heat for the heat pump.

The cost of obtaining heat from the heat pump therefore lowers the electrical cost to about $225.00 per season.

If one could find a well furnishing water at 60 degrees F., the coefficient of performance can be raised to as much as 4 or 5 and this factor will make the cost of operation for the pump very close to the cost of heating with gas or oil.

26-6. CONDENSERS AND COOLING COILS

The coil mounted inside the house is a standard finned coil used with a blower. The fins are spaced 1/2 to 1/4 in. apart and the fins extend about 1/2 in. from the tubing or prime surface.

The outside coil comes in a variety of designs. The coil design depends on what substance the coil is to releas its heat to or pick up its heat from The various types of coils classified a to the heat medium are:

1. Air coil
2. Lake water coil
3. Well water coil
4. Ground coil

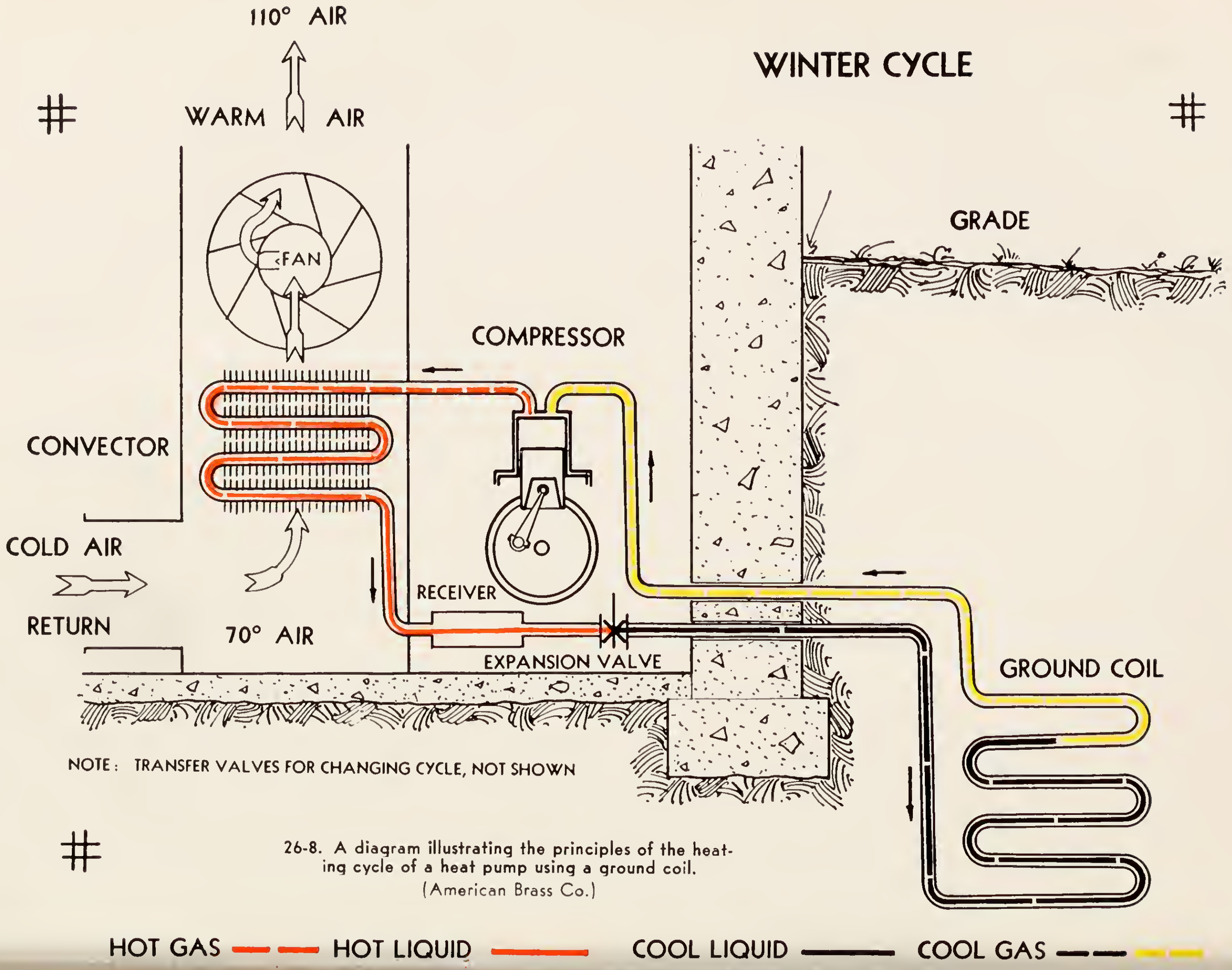
26-7. AIR COIL

The easiest to install and the leas expensive of the outdoor coils for hea pump use is a coil used to release it heat to the outside air, or to pick u heat from the outside air. This typ coil has many advantages in climate where the outdoor temperatures do nc vary more than from 30 F. to 110 F.

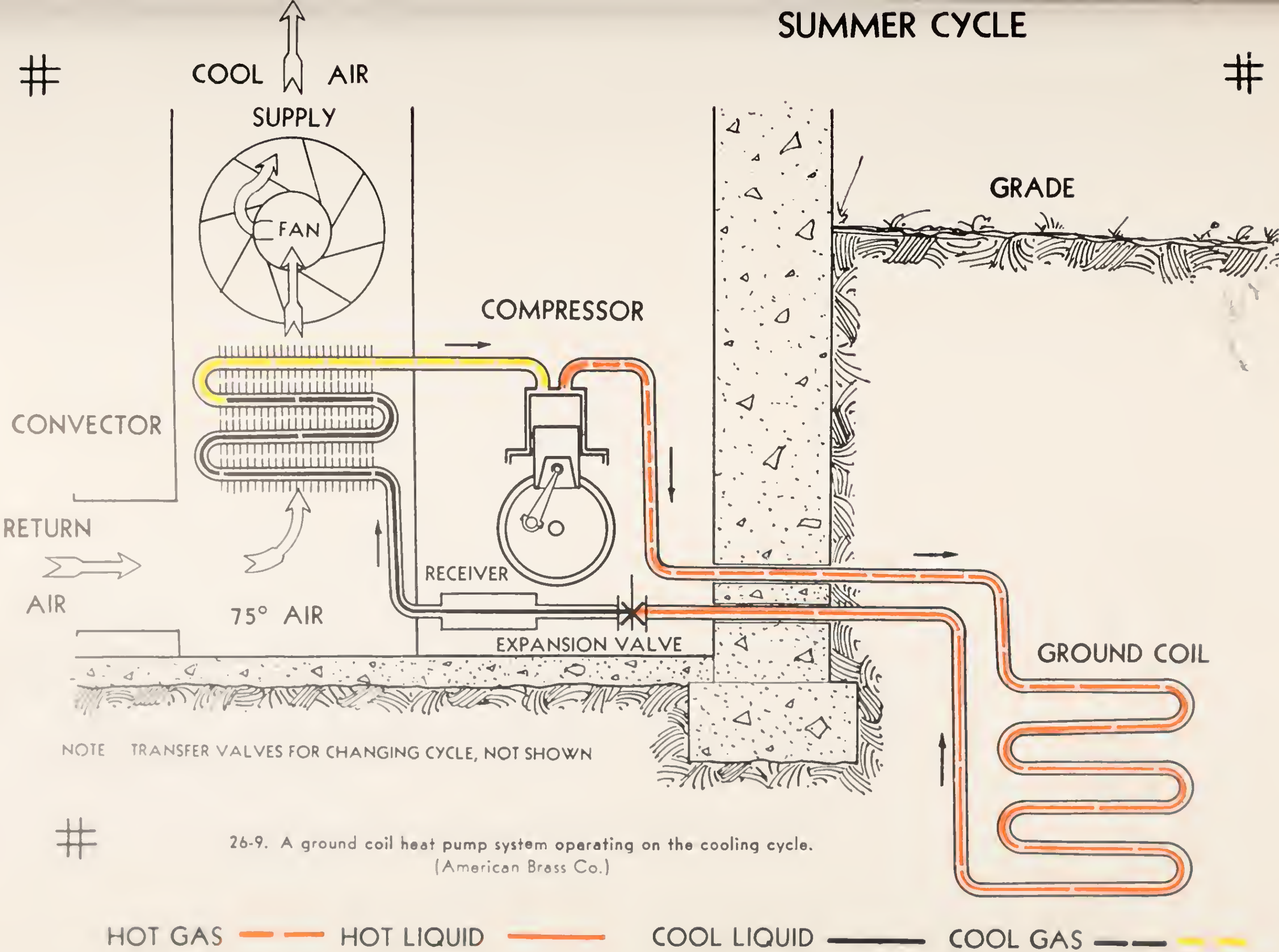
The coil itself is a standard hea transfer coil with tubing for primar surface and extended fins bonded to th tubing. A blower is mounted in th housing that protects the coil from th weather. The coils have been mounte on the outside wall of the house, on th roof and in a separate shelter adjacer to the house.

26-8. LAKE WATER COIL

As has been explained, the per formance of a heat pump increases i efficiency as the condensing and coolir coil temperature approach each othe Therefore, during the heating cycl if a warmer source can be found tha the ambient air, an increase in per formance can be expected. Several in stallations have been tried where th outside coil is approximately 10C feet of tubing dropped on the bottom a lake adjacent to the premises. Th coil if installed at the bottom of th lake has a more consistent temperatu than otherwise. Installations of this typ have been used as far north as Minr eapolis, Minn.



26-8. A diagram illustrating the principles of the heating cycle of a heat pump using a ground coil. (American Brass Co.)



26-9. A ground coil heat pump system operating on the cooling cycle.
(American Brass Co.)

26-9. WELL WATER COIL

Well water may provide a very efficient heat pick up unit for heating and a good heat dissipator during the cooling cycle.

The cost of the well is one disadvantage but its cost is soon offset by the lower cost of operation.

The most popular method of using well water is to pump the water out of the well and then after heat has been removed from the water or released to it, the water is returned to the well.

When the well water is at 60 F., a condensing temperature of 80 F. can be used during the cooling cycle while a cooling coil temperature of 40 F. can be used during the heating cycle.

26-10. GROUND COIL

The type of outside coil which is receiving considerable attention is a ground coil. It has been found that regardless of the latitude and the air temperature changes, that the temperature in the ground at a depth of 4 to 6 ft. changes very little. These temperatures average between 40 F. and 60 F.

Therefore if a coil is buried in the ground at a depth of 4 to 6 ft. and it has sufficient heat transfer surface it can be very efficiently used as an outdoor coil for both the heating and cooling cycle. Fig. 26-8 illustrates a ground coil system as it operates during the winter. In actual construction the ground coil is installed in a flat position. Also the air return is usually a split-air system with a fresh air make-up duct. Fig. 26-9 illustrates the same basic system used as a comfort cooling mechanism. In actual practice, valves would be used to flow the condensed refrigerant first through the liquid receiver and then through the expansion valve from left to right before the reduced pressure refrigerant enters the cooling coil in the duct.

Several installations have been made using a combination of air coils and either a lake coil, well coil, or ground coil. The air coil is used alone when the outdoor temperature permits efficient operation but when the outside air becomes too cold or too warm the auxiliary coil is connected into the system.

26-11. COMPRESSORS

The compressor used in heat pumps is of standard construction. Units up to 5 H.P. use single stage compressors of constant capacity. The trend is to use hermetic compressor-motor combinations.

Because the pumping load varies extensively during the day and also during the change of seasons, variable capacity compressors are now being used. These compressors vary their capacity by operating valves which unload a compressor cylinder or cylinders into clearance pockets.

The mechanism used is hydraulicly or electrically operated to hold open the intake valves or to open a passage to a clearance pocket for that cylinder or cylinders that are to be unloaded.

26-12. MOTORS

The smaller heat pumps, 1/3 to 1 ton, use standard single-phase motors usually with a capacitor starting winding. Three phase motors are preferred in units over one ton capacity mainly for electrical economy. The single phase motors should be operated at 220 volts if possible.

As stated before, most of the units are now of the hermetic design.

26-13. REFRIGERANT CONTROLS

Both the thermostatic expansion valve and the capillary tube refrigerant

controls are being used with heat pumps. The change-over valves are much simpler in those units that use the capillary tube control because the flow of refrigerant can be reversed through the tube for pressure reducing purposes. In this type of installation, a strainer must be installed at both ends of the tube. Fig. 26-10 illustrates a heat pump using a capillary tube and a solenoid reversing valve, operating on a cooling cycle. The wiring diagram and a diagram showing the control contact for the cooling cycle are shown in Fig. 26-11.

Fig. 26-12 illustrates a heat pump using a capillary tube and a solenoid operated reversing valve operating on a heating cycle.

The wiring diagram and a diagram showing the control contacts for the heating cycle are shown in Fig. 26-13.

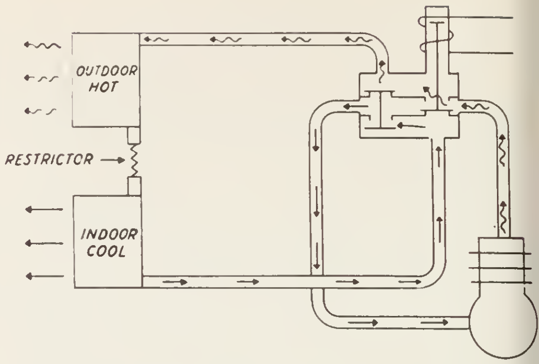
The thermostat which operates the four way valve and also controls the temperature is shown in Fig. 26-14.

The wiring of heat pumps depends mainly on whether the motor is connected directly to the line or whether some kind of starter (magnetic or transformer) is used. See Fig. 26-15.

26-14. REFRIGERANT LINES

The suction lines and liquid lines of the heat pump are unusual in that both lines are constructed large enough to handle the refrigerant in a gaseous form. This is because the use of the lines may be reversed as the cycles are reversed. A liquid line, while on a cooling cycle, may become a suction line when the unit is used for heating.

The lines are normally fitted with streamline soldered connections. Silver brazing is the most popular. Flexible connections are usually installed in the lines at the compressor to eliminate noise and to allow for some vibration of the compressor.



26-10. A heat pump with a capillary tube refrigerant control operating on a cooling cycle (indoor cool). The bent arrow lines mean high temperature. The straight arrow lines mean low temperature.
(Ranco, Inc.)

26-15. MOTOR CONTROLS

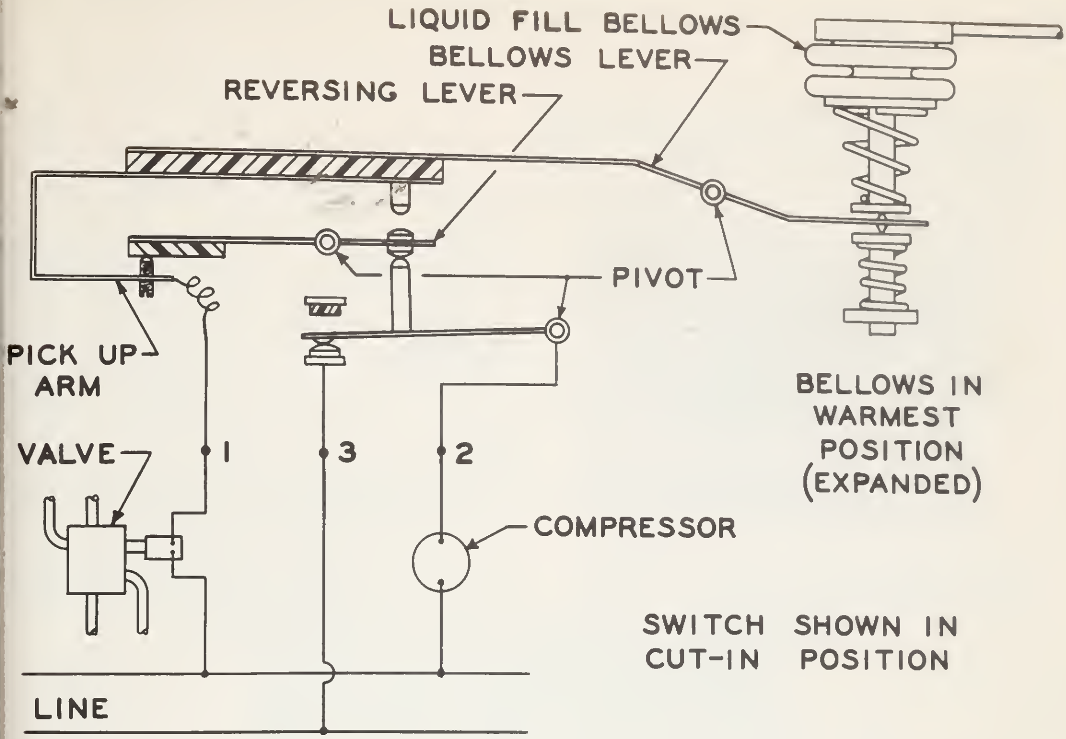
A double set of automatic controls is usually required for the heat pump. A thermostat designed for heating is needed for cold weather conditions and a thermostat designed for cooling conditions is needed for warm weather. Humidstats are not used extensively as yet although they are needed for complete automatic control.

26-16. REVERSING VALVES

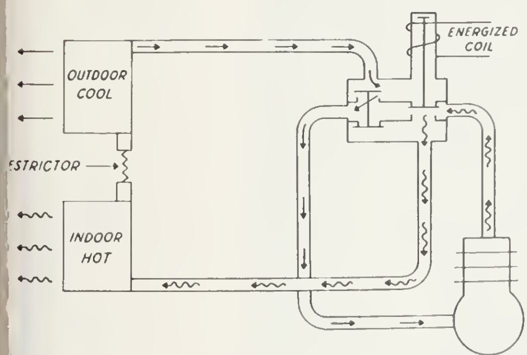
Several different types of valves are used in heat pumps to reverse the refrigerant flow. At least six one-way valves are needed. These valves may be electrically operated (solenoids) or manually operated.

Some units use three-way valves, either manually or electrically operated. These valves have one opening to the compressor, one opening to the condenser, and one to the cooling coil. Two of these valves are needed to operate the unit.

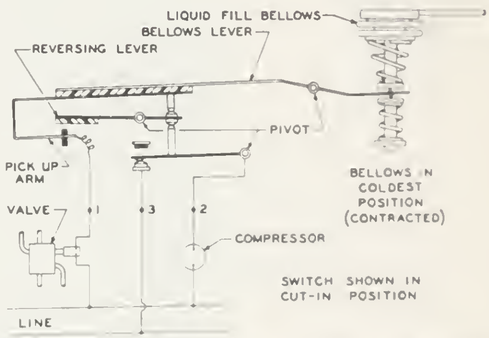
A four way valve may be used to reverse the flow of refrigerant. It is operated by one valve stem movement which closes and opens several ports in one valve body, either by moving the stem manually or electrically.



26-11. A wiring diagram of a heat pump showing the electrical connections for the cooling cycle.
(Ranco, Inc.)



26-12. A heat pump operating on the heating cycle. The crooked arrows indicate high temperature. The straight arrows indicate low temperatures. Note the use of a 4-way valve.
(Ranco, Inc.)



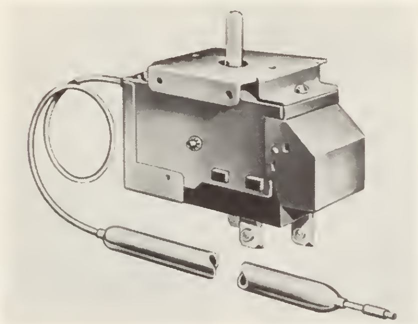
26-13. The electrical connections during the heating cycle of the heat pump and using the thermostat shown in Figure 26-19.
(Ranco, Inc.)

The system is easily reversed with one of these valves. The valve is popular in the small tonnage units such as window units and other air-to-air units.

A four-way valve that is operated by pressure is shown in Fig. 26-16. A solenoid valve controls the pressure at the top portion of the solenoid valve. When the pilot valve is energized, the compressor low side pressure is imposed on the four way valve and all three internal valves are lifted, producing the cooling cycle. Coil E is the indoor coil while Coil F is the outdoor coil.

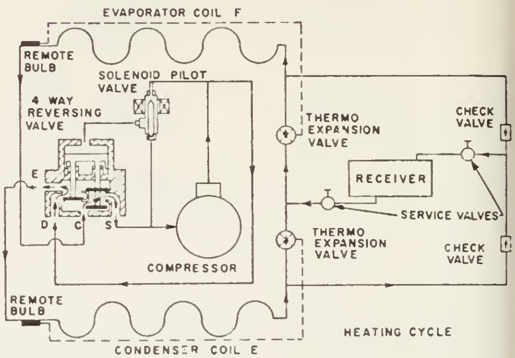
When the solenoid pilot valve circuit

is opened, manually or by a thermostat, the solenoid valve closes and the three valves inside the four-way valve drop,

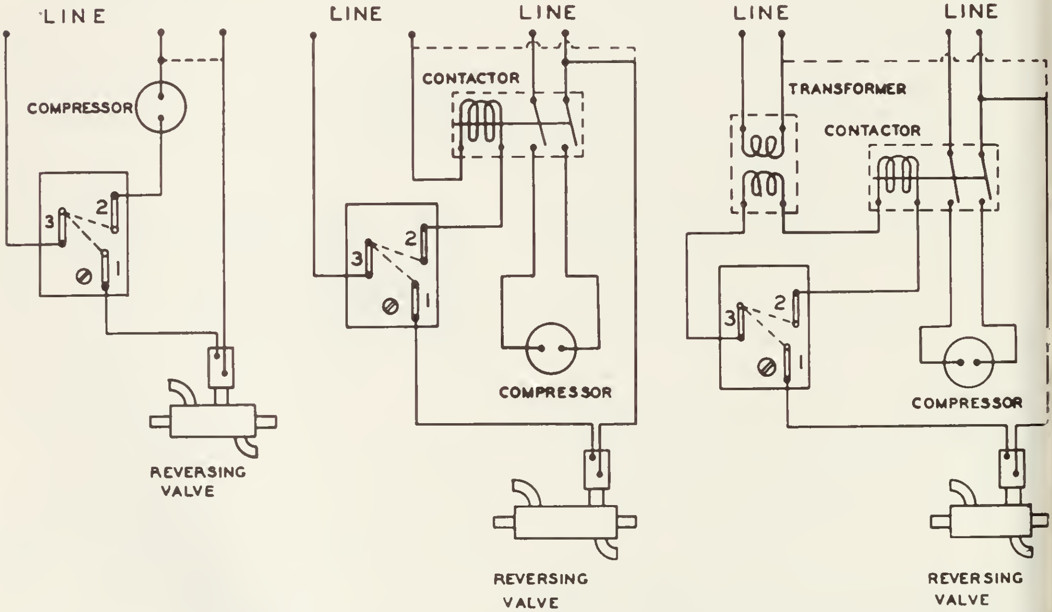


26-14. A thermostat for controlling an air conditioner heat pump. This is shown in Fig. 26-11 and 26-13.
(Ranco, Inc.)

During the cooling cycle, the upper



26-16. A heat pump schematic diagram which uses a special four way reversing valve. As shown it is operating on the heating cycle.
(Alco Valve Co.)



26-15. Three wiring diagrams for heat pumps. No special mechanism is used on the diagram at the left. The middle diagram shows a line coil magnetic starter. The diagram on the right shows a low voltage coil magnetic starter.
(Ranco, Inc.)

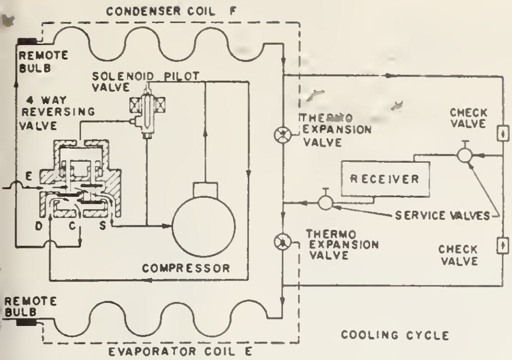
and the refrigerant flow to the coils is reversed.

This heat pump uses two thermostater expansion valves and two check valves to permit reversing the refrigerant flow around the thermostatic expansion valve.

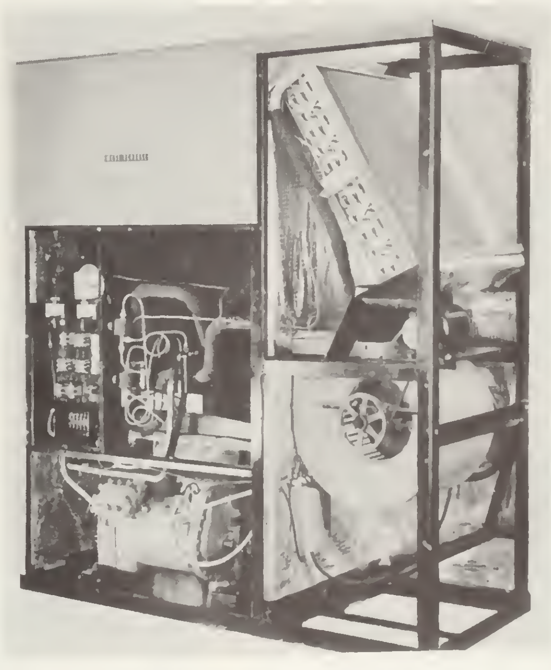
thermostatic expansion valve is not used.

Fig. 26-17 illustrates this same system operating as a heating unit. Coil E now is the condenser and is releasing heat to the indoors.

Fig. 26-18 illustrates a modern heat



26-17. A heat pump schematic diagram which uses one four way reversing valve. A solenoid pilot valve is used to operate the four way valve. As shown it is operating on the cooling cycle.
(Alco Valve Co.)

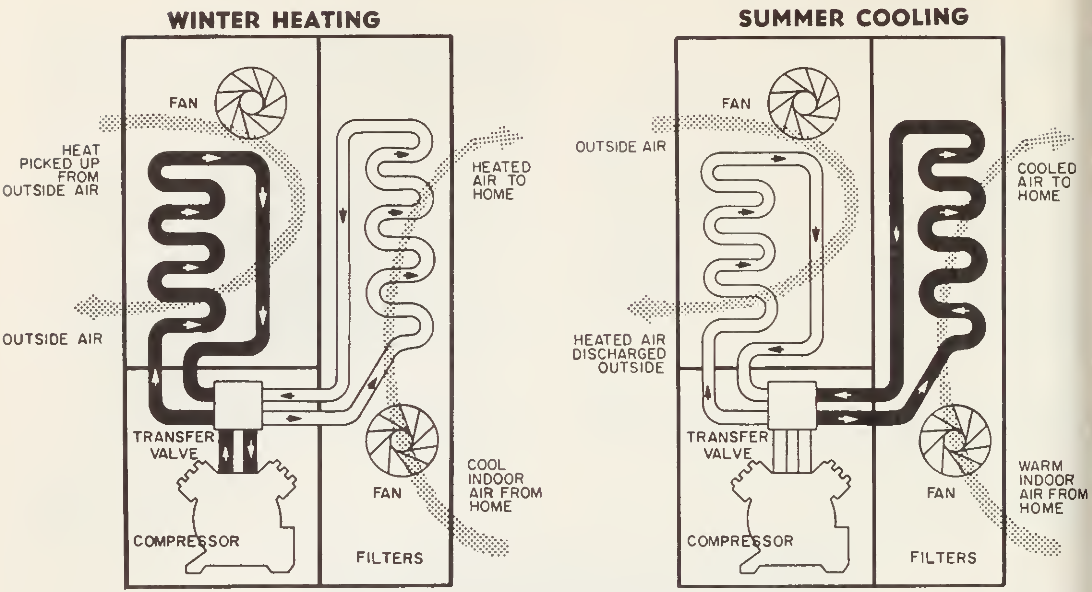


26-18. A modern heat pump mechanism.
(Westinghouse Electric Corp.)

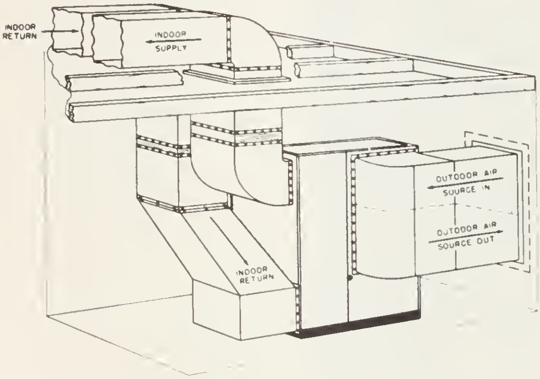
pump mechanism. This design has air ducts that bring outside air into the unit and discharges this air outdoors. This outdoor coil is in the upper left corner of the picture. The indoor air passes through the filters and the coil shown. During the heating season the exposed coil is the condenser, and during the cooling season the exposed coil is the cooling coil. A diagrammatic sketch of the systems operation may be seen in Fig. 26-19. Notice that two separate circulating fins are used. The black coil is the warm coil and the white coil is the cooling coil in each illustration. These units are installed in a home, either in the basement, or on the first floor. Fig. 26-20 shows a typical first floor utility room installation.

26-17. REVIEW QUESTIONS

1. What part of the refrigerating unit releases heat?
2. Who first proposed the use of a refrigerating unit for heating?
3. How many heat transfer surfaces does a heat pump have?
4. How can heat be removed from 0 F. air?
5. What are the two operating



26-19. A diagram illustrating the air and refrigerant circuits in a heat pump during heating and cooling operation. (Westinghouse Electric Corp.)



26-20. A diagram of a heat pump installation in a house.

cycles of a heat pump?

6. Under what conditions is a heat pump the most efficient?
7. What is coefficient of performance?
8. Is it less expensive to heat with electrical resistors or with a heat pump?
9. How many Btu/hr. are generated by one kwhr. through direct electrical resistance?
10. List one disadvantage of each type of coil.
11. What are the various types of outdoors coils?
12. What type of coil is used indoors?
13. What outdoor coils are used when dual coils are used?
14. Why is the capillary tube especially advantageous to use in heat pumps?
15. Explain the operation of a three way valve used to reverse the refrigerant flow.

Chapter 27

AUTOMOBILE AIR CONDITIONING

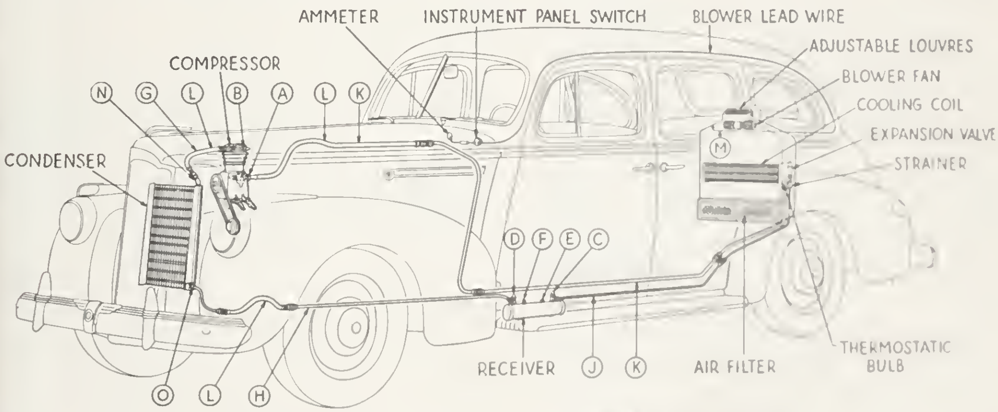
Air conditioning our surroundings is an important factor affecting our comfort. We are now accustomed to living in air conditioned homes and working in air conditioned buildings. Accordingly we are made more conscious of the discomfort of hot and humid vehicles in which we travel. It is only natural that the vehicles in which we travel should be air conditioned also.

27-1. DEVELOPMENT

The purpose of the air conditioning system for automobiles and buses is identical to the general purpose of air conditioning as stated in Chapter 22.

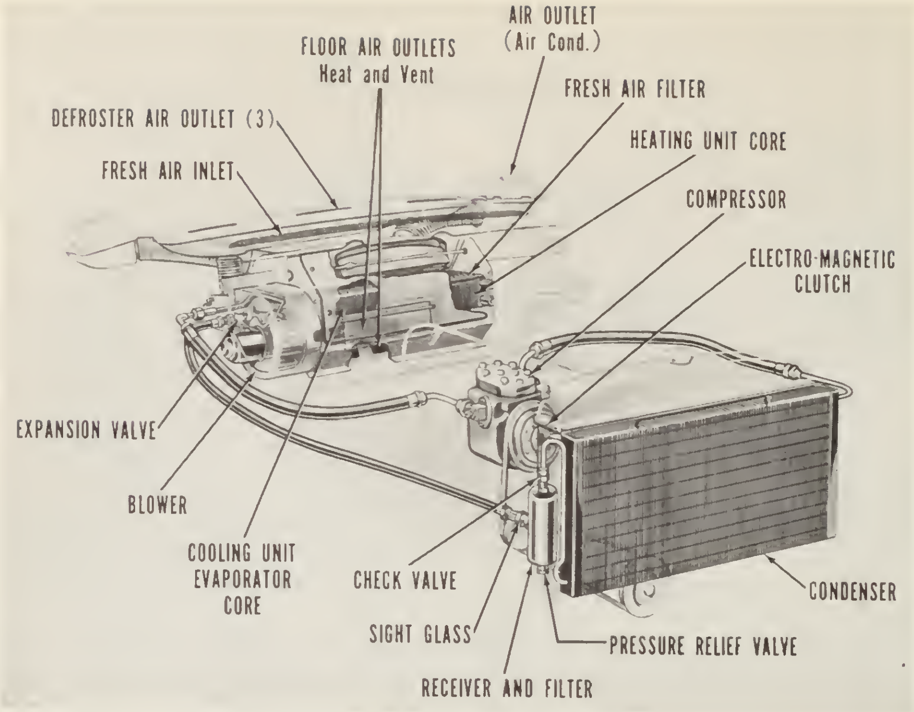
The first kind of air conditioning applied to moving vehicles was the heater. Ventilation was crudely and easily obtained by opening windows. Prior to World War II vehicles were introduced that had "air conditioning," but the term only meant that the apparatus controlled the heating, ventilation, and filtering of the air.

During the late thirties some passenger buses were air conditioned on an experimental basis. The Packard



A—Compressor Suction Service Valve
B—Compressor Discharge
C—Receiver Shut-off Valve
D—Condenser Shut-off Valve
E—Fusible Plug
F—Freon Level Tester
G—1/2" High Pressure Gas Line
H—1/2" High Pressure Liquid Line
J—3/8" High Pressure Liquid Line
K—5/8" Low Pressure Gas Line
L—Flexible Line (Vibration Eliminator)
M—Blower Fan Ground Wire
N—Condenser Inlet Connection
O—Condenser Outlet Connection

27-1. An early comfort cooling system installed in an automobile. (Studebaker-Packard Corp.)



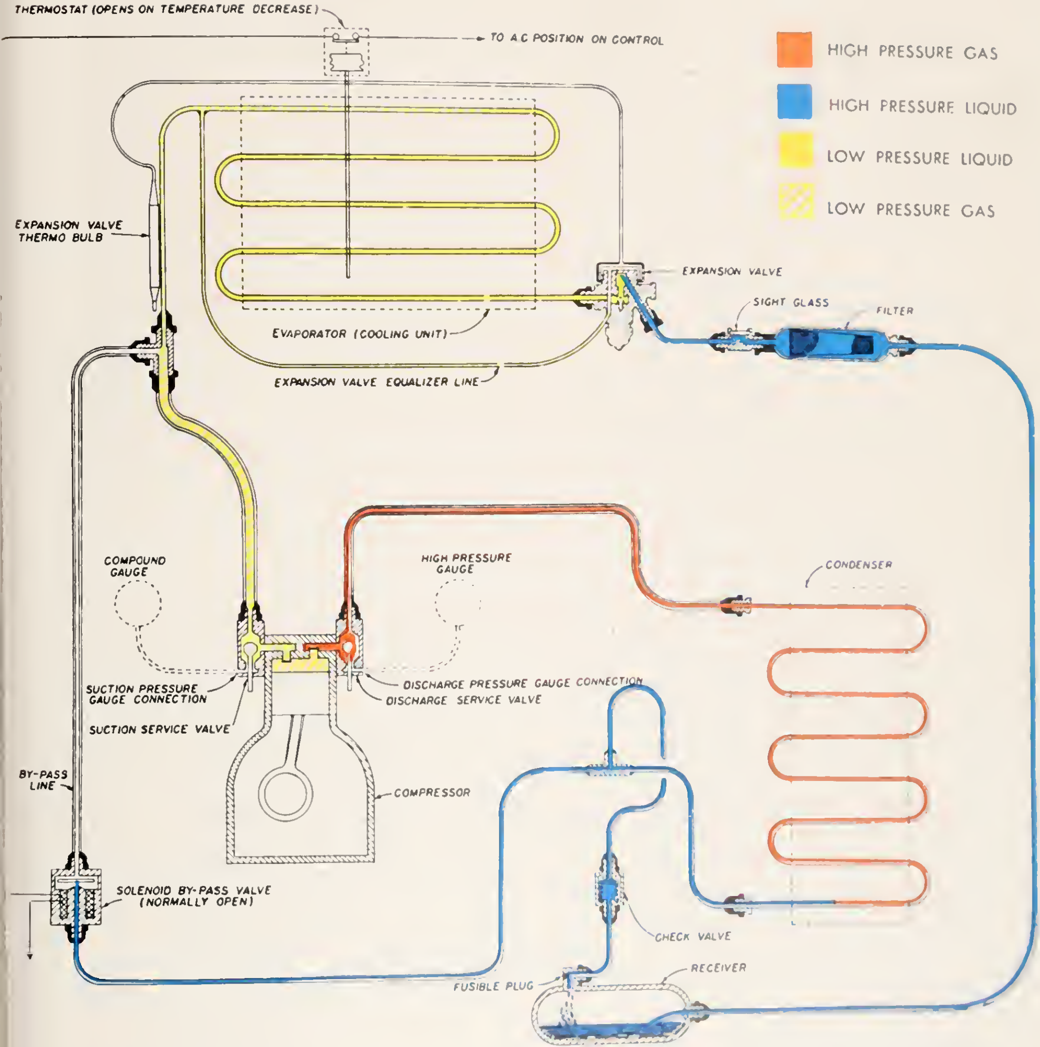
27-2. All season air conditioner for 1958 Ambassador and Rambler cars, which combines cooling, heating, ventilating and defrosting in one unit.

Motor Car Co. was the only company offering comfort cooling apparatus, factory installed, prior to 1941. See Fig. 27-1.

Since World War II, completely air conditioned automobiles of most makes have been available. There has been a very rapid increase in the use of the complete air conditioning unit for automobiles. A late model comfort cooling unit for automobiles is shown in Fig. 27-2. In this installation the compressor is mounted above the engine and is driven by a belt from the front end of the engine. The condenser is mounted ahead of the car radiator. The liquid refrigerant flows from the condenser to the liquid receiver and through a filter to the cooling coil. The vaporized refrigerant then flows back through the suction line to the compressor. A blower forces air from the inside of the car through the cooling coil and circulates it to the interior of the car by means of the grilles at each end of the dash. The refrigeration cycle diagram for this air conditioner is shown in Fig. 27-3.

On the air conditioning cycle, refrigerant gas enters the compressor through the suction service valve (low side). The gas is then drawn into the cylinder and compressed by the piston and discharged through the discharge service valve into the condenser (high side). The heat of compression and the latent heat of vaporization are given up to the air flowing past the condenser and the refrigerant is liquefied. The liquid receiver stores the liquid refrigerant which is still under high pressure. The liquid receiver is equipped with a fusible plug set to discharge at 367 F. in the event of a fire.

The liquid refrigerant flows through a filter then through a sight glass. The



27-3. A refrigeration cycle diagram for a typical car air conditioning system. (Nash Div., American Motors Corp.)

sight glass provides a quick and easy way of checking the refrigerant charge in the system. The presence of bubbles or foam indicates a shortage of refrigerant. The liquid refrigerant flows to the thermostatic expansion valve which is the dividing point between the high and the low pressure side. The control bulb of the thermostatic expansion valve is clamped to the suction line as it leaves the cooling coil.

During the "on" cycle the expansion valve provides a throttling action which controls the quantity of refrigerant in the cooling coil and it prevents liquid refrigerant from reaching the compressor. The equalizer connection is used on all high capacity systems. It assures operation of the cooling unit at maximum capacity at all times. The cooling coil (evaporator) receives the liquid refrigerant at low pressure and the refrigerant evaporates and absorbs heat from the air passing over the surface of the cooling coil.

Electrically driven blowers assist in circulating air over the cooling coils and through the interior of the car. The evaporated refrigerant is returned through the suction line to the suction service valve and the cycle is repeated.

If the cycle were repeated continuously the temperature in the car would drop to an uncomfortable level and the cooling coil would frost over. To prevent this condition an automatic by-pass is built into the system. The components of this part of the system are the solenoid by-pass valve, temperature control thermostat by-pass line, and check valve. The solenoid valve is wired in series with the temperature control thermostat and the air conditioning switch. When a temperature of 32 F. is reached, the solenoid is de-energized and the refrigerant by-pass circuit is opened. High pressure refrigerant vapor from the condenser flows through the solenoid valve, the by-pass line, and back to the suction service valve of the compressor. The cooling coil warms up and defrosts. As soon as the cooling coil reaches 37 F. the solenoid valve closes and the cooling cycle is again in operation.

When the air conditioning system is not turned on, such as in winter when the heater is used, the mechanism is not in operation. This is accomplished by not energizing a magnetic clutch on the compressor pulley which allows the compressor pulley to free wheel when the air conditioning is not turned on.

27-2. APPLICATION PROBLEMS

The greatest problem in automobile air conditioning comes from the fact that the compressor is belt-driven from the engine, and the compressor speed will vary with the engine speed which of course varies continuously as the car speed changes. The compressor must have enough capacity to give sufficient cooling at idling speed on the hottest day. Naturally considerable excess capacity is provided at high speed and under cool weather conditions. This condition brings in problems in both the matter of controlling the temperature and the control of refrigerant (both liquid and gas) within the cycle. If the compressor is operating rapidly and little or no refrigeration is required the high side pressure will build up and the low side pressure will drop very low.

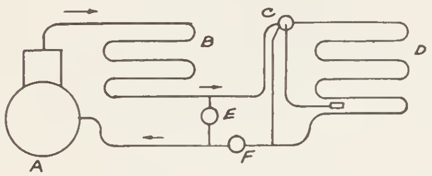
Dropping the low side pressure lowers the cooling coil (evaporation) temperature. The cooling coil temperature must not be allowed to drop below 32 F. If it should operate at a temperature of 32 F. or lower for any length of time it would freeze over and fill with ice and become inoperative.

Also operating the system under a very low low side pressure will cause oil pumping which may damage the compressor valves and if continued may burn out the compressor.

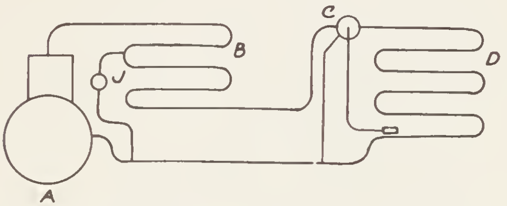
Various cycle and mechanical systems have been devised to overcome these problems.

27-3. SOME TYPICAL OPERATING CYCLES

There are four basic cycle and



27-4. A cycle diagram of a pressure operated by-pass and low side pressure refrigerator system. A. compressor; B. condenser; C. Thermostatic expansion valve; D. Cooling coil (evaporator); E. Low side pressure operated by-pass; F. Evaporator pressure control.



27-5. A cycle diagram of a pressure operated by-pass. A. Compressor; B. Condenser; C Thermostatic expansion valve; D. Cooling coil (evaporator); J. Pressure operated by-pass valve.

mechanical systems in common use. They are:

1. Pressure operated by-pass and low side pressure regulators.
2. Pressure operated by-pass.
3. Solenoid operated by-pass.
4. Magnetic clutch.

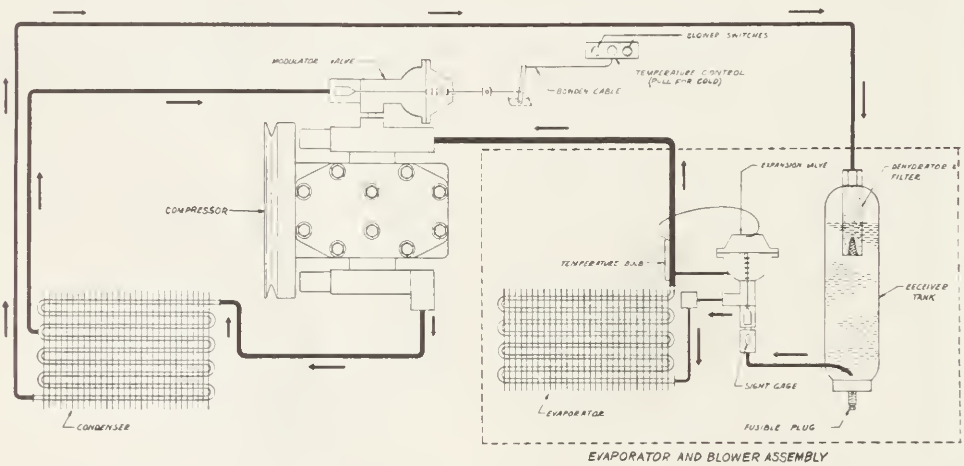
27-4. PRESSURE OPERATED BY-PASS AND LOW SIDE PRESSURE REGULATOR

A diagram of a pressure operated by-pass and low side pressure regulator is given in Fig. 27-4. In this system the cooling temperature is held about 32 F. by means of the evaporator pressure control (F) which does not allow the pressure in the coil to drop below a pressure corresponding to 32 F.

The compressor low side pressure is regulated by the low side pressure operated by-pass (E). This control operates to allow liquid refrigerant to by-pass through (E) to the low side at any time that the low side pressure drops below the setting of the valve.

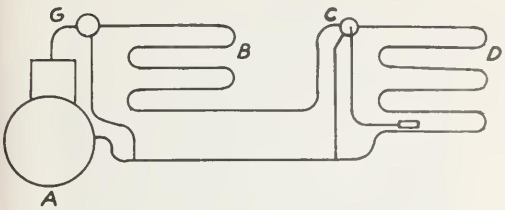
27-5. PRESSURE OPERATED BY-PASS VALVE

A diagram of a pressure operated,



27-6. A cycle diagram for a pressure operated by-pass. The modulator valve is the pressure by-pass in this system. Note the solid core type dehydrator and filter at the entrance to the liquid receiver. (Studebaker Div., Studebaker-Packard Corp.)

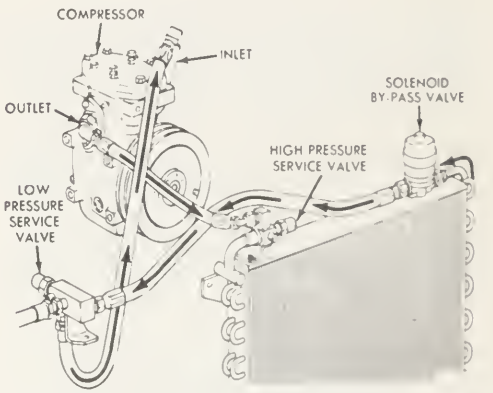
by-pass is given in Fig. 27-5. In this system the pressure operated by-pass valve (J) is connected between the compressor discharge (high side) and the compressor suction line (low side). It is set to open and by-pass hot gas from the high side to the low side when the pressure difference reaches the setting of the valve. This cycle does not give as even a coil temperature as the one described in the preceding paragraph. See Fig. 27-6.



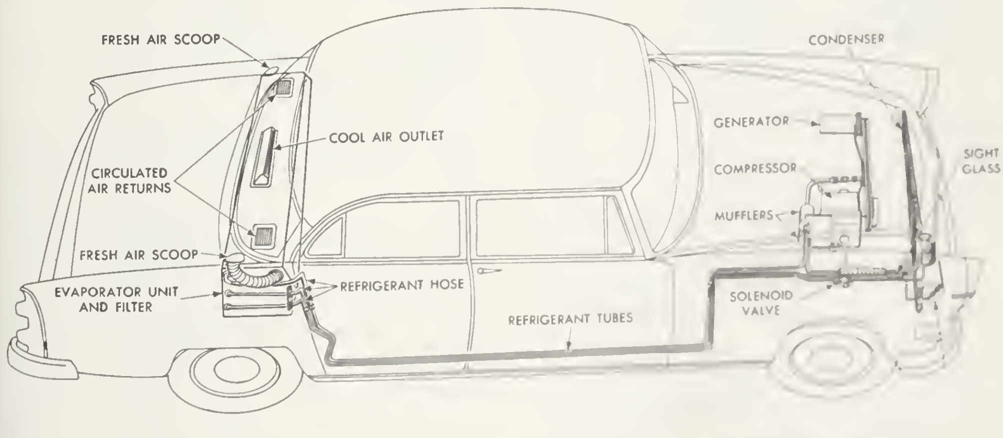
27-7. A cycle diagram of a solenoid operated by-pass. A. Compressor; B. Condenser; C. Thermostatic expansion valve; D. Cooling coil (evaporator); E. Solenoid operated by-pass valve.

27-6. SOLENOID OPERATING BY-PASS

A diagram of the solenoid operated by-pass is given in Fig. 27-7. In this system a thermostat mounted on the cooling coil (evaporator) operates to open a solenoid valve and by-pass hot gas from the high side to the low side when the temperature of the cooling coil drops to 32 F. Since the solenoid valve is either closed or wide open it does not give the throttling effect of the pressure operated valve. This is a popular type of system and it gives good results. Fig. 27-8 and Fig. 27-9 show installation diagrams for this type of system.



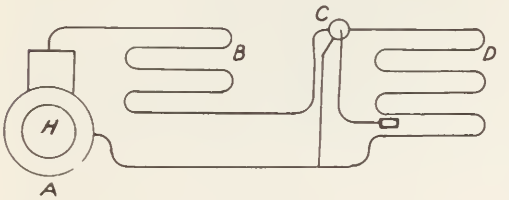
27-9. The path of the by-passed refrigerant when the solenoid valve is not energized. When the thermostat calls for more cooling the solenoid is energized and the by-pass is closed.
(Ford Motor Co.)



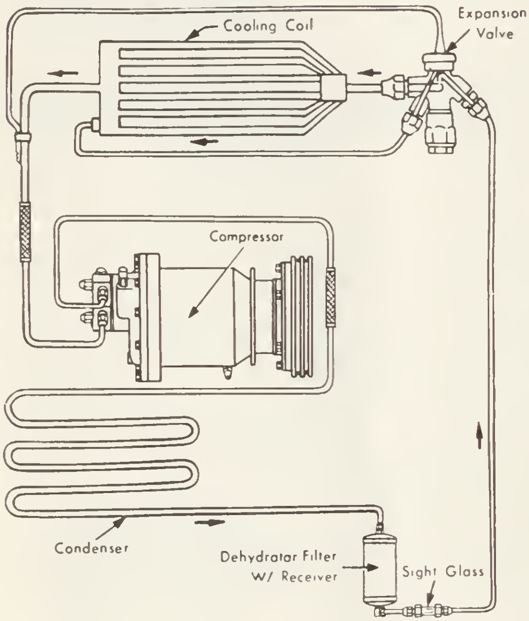
27-8. An installation diagram for a solenoid operated by-pass system.
(Dodge Div., Chrysler Corp.)

27-7. MAGNETIC CLUTCH

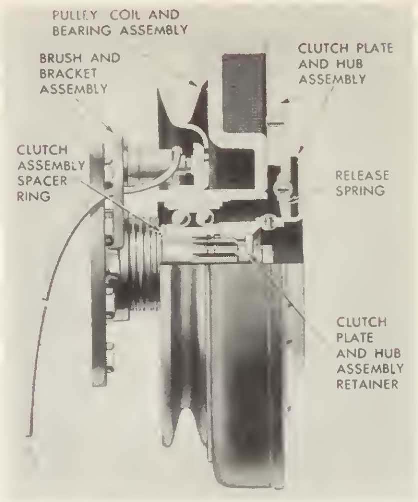
A diagram of a magnetic clutch controlled compressor is shown in Fig. 27-10. In this system a thermostat on the cooling coil (evaporator) operates an electric circuit to a magnetic clutch on the compressor drive pulley. When the temperature of the cooling coil is brought down to a predetermined setting, the thermostat opens the electric circuit to the magnetic clutch on the compressor drive pulley and the pulley "free wheels" on the compressor shaft and the compressor stops. This system gives both good coil temperature control and even pressure control on both the high side and the low side. See Fig. 27-11.



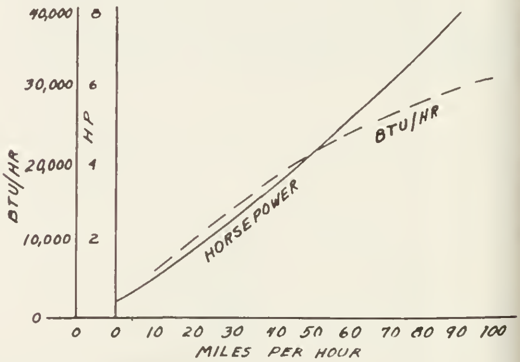
27-10. A cycle diagram of a magnetic clutch operated temperature control. A. Compressor; B. Condenser; C. Thermostatic expansion valve; D. Cooling coil evaporater; H. Magnetic clutch on compressor drive pulley.



27-11. A magnetic clutch controlled compressor. This cycle diagram shows the vibration absorption units in the suction and liquid lines also the dehydrator-filter installed in the liquid receiver. A sight glass in the liquid line will indicate by bubbles if the system is low on refrigerant. (Cadillac Motor Car Div., General Motors Corp.)



27-12. A magnetic clutch used to connect or disconnect a compressor from the drive pulley. (Pontiac Motor Div., General Motors Corp.)



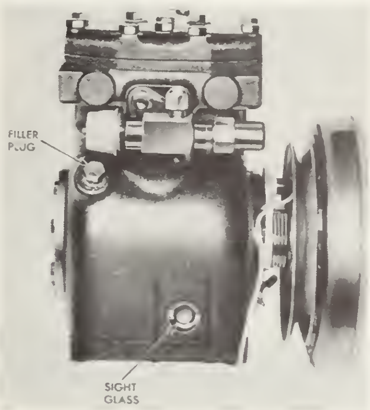
27-13. A curve showing the relationship between car speed, heat load and horse power required to drive the automobile cooling mechanism.

A magnetic clutch is sometimes used on a by-pass system as a means of turning the air conditioning system on and off but may not be used for temperature control. The construction of the magnetic clutch in this case is somewhat different, Fig. 27-12.

27-8. PERFORMANCE

The unit must be of a size that has at least a three ton capacity at a vehicle speed of about 50 miles per hour. The belt driven compressor and its component parts works very satisfactorily, Fig. 27-13.

As the automobile slows down, the capacity will decrease, and as the automobile speeds up, the capacity will increase. This variation in capacity is



27-14. A two cylinder compressor with a magnetic clutch. Note the oil filter plug and the oil level sight glass.
(Pontiac Motor Div., General Motors Corp.)

somewhat parallel with the changing heat load except at one critical interval, parked or in slow moving traffic. At these critical times the compressor capacity is far below its needed capacity. At present, the only recourse is to idle the engine at a higher speed and to travel in traffic in some intermediate gear to enable higher engine speeds.

The refrigerating system can consume as much as 8 H.P. from the engine at high speeds and at this high speed the unit capacity will be approximately 36,000 Btu/hr. or three (3) tons capacity. This means that about 2 1/2 H.P. are needed for each ton of refrigeration effect. This compares to the use of 1 H.P. for each ton of refrigeration in a motor driven constant speed compressor comparably built and with the cooling coil and condenser more ideally located.

When heating is required, the typical hot water coil using engine heat is installed in the air duct. The same fans and also the same filters may be used during the cooling cycle and during the heating cycle.

27-9. COMPRESSOR

The compressors used at present are mostly belt-driven from the engine. They operate at slightly above engine r.p.m. Therefore with the engine idling, the compressors will revolve at approximately 600 r.p.m. and at maximum engine speeds, the compressor will revolve at near 5000 r.p.m., Fig. 27-14.

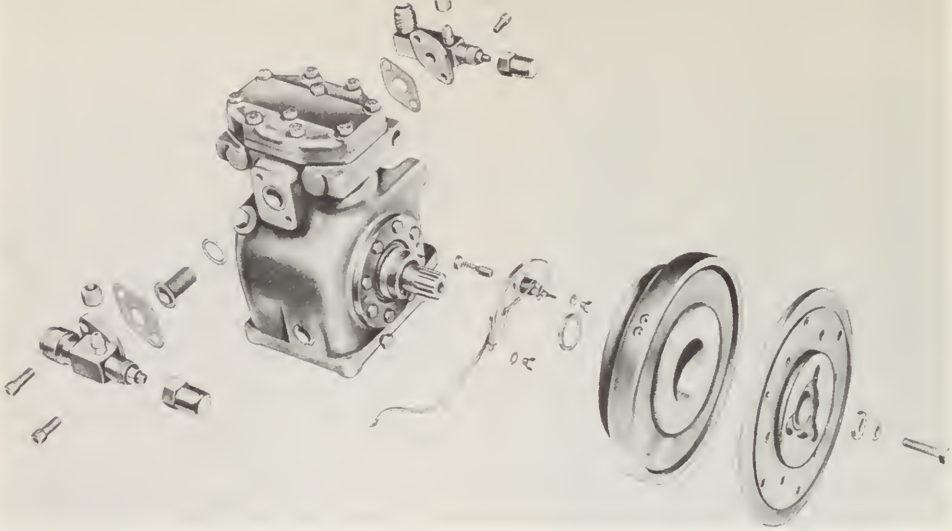
The compressor must be designed to be fairly efficient and trouble free under all of these conditions of variable speed and low and high pressures.

Crankshaft seals must be of a heavy duty type; the moving parts must be balanced for all the varying speeds. The compressor breathing, volumetric efficiency, must stay up to a certain minimum regardless of the speed. Therefore, the valve and valve port design must be excellent.

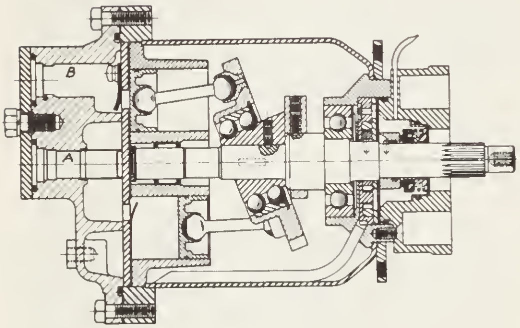
Either a rotary or reciprocating compressor may be used. They are identical in operation to those explained in previous chapters.

Several new designs are being tested which involve putting the compressor in the trunk of the car or between the trunk and the rear seat of the car and driven by electric motors, hydraulic motors, or mechanical drive by means of a flexible shaft. Some of these compressors are hermetic. The packaged air conditioning unit is adaptable to heat pump use and could be used for heating as well as cooling.

Service valves are provided for mounting gauges in the low pressure



27-15. An exploded view of an automobile air conditioning compressor.
(Pontiac Motor Div., General Motors Corp.)

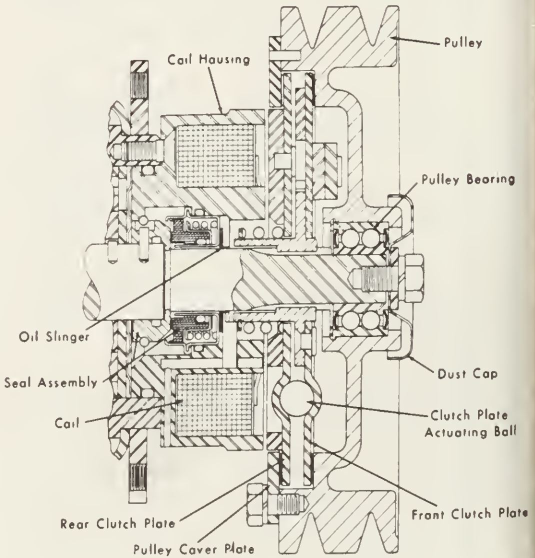


27-16. A section drawing of a wobble plate type compressor. An exhaust valve is shown at the upper left. The connecting rods are of the ball and socket type.
(Cadillac Motor Div., General Motors Corp.)

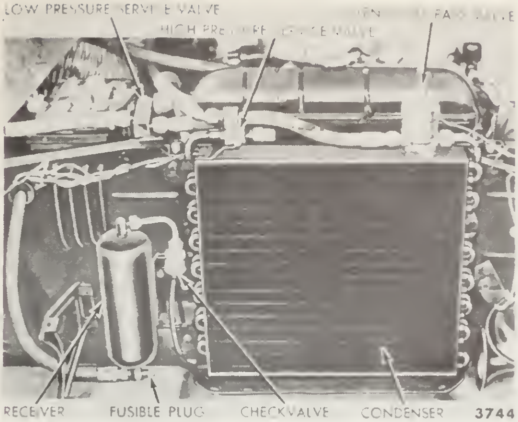
side and the high pressure side of the system. See Fig. 27-15.

The Cadillac Div. of the General Motors Corp. uses a wobble plate type compressor having five cylinders, Fig. 27-16. This compressor uses a wobble plate mounted on a double row of ball bearings. These bearings run on an inclined race which is fastened to the rotating shaft. The suction line connection is centered with the shaft. An oil pump is mounted between the single row ball bearings and the seal.

The compressor uses a magnetic clutch. The solenoid coil is stationary and when energized, it moves the inner clutch plate into contact with the pulley. Actuating balls placed in depressions between the two clutch plates force the plates apart as the inner plate tends to revolve with the pulley. In this way the necessary driving friction is obtained, Fig. 27-17. This also shows details of the crankshaft seal.



27-17. Details of the magnetic clutch used on Cadillac air conditioning compressors.
(Cadillac Motor Car Div., General Motors Corp.)



27-18. The details of an air cooled condenser mounted in front of the automobile radiator. (Ford Motor Co.)

27-10. CONDENSER

The condenser is usually mounted in front of the lower part of the car radiator. The discharge line from the compressor to the condenser usually has a vibration absorber mounted in it.

The condenser is either the one, two or three pass finned tube type. It is firmly fastened to the radiator shell, and much of the air going into the engine compartment and through the radiator goes through the condenser first.

The condenser is the standard construction air cooled type. Fig. 27-18.

If the condenser is mounted in the trunk, a separate fan is usually used to force air through the condenser.

27-19. A trunk mounted type cooling coil (evaporator). Note the sight gauge in the liquid line at the attachment to the thermostatic expansion valve. The end air ducts discharge the cooled air to the passenger compartment. The center lines are for return to the cooling unit. (Studebaker Div., Studebaker-Packard Corp.)

The refrigerant lines are usually copper or flexible lines. Silver brazed connections are used wherever possible, but flared connections are needed where the units must be disconnected for servicing. It is important that the copper tubing be prevented from touching any steel parts of the car. Wear and corrosion would quickly cause leaks at the contact points.

27-11. COOLING COIL

The cooling coil of the automotive air conditioner is the finned, forced convection type. It is enclosed in a metal housing that also serves as a duct for the conditioned air. A moisture drain pan and drain pipe must also be incorporated in the unit, Fig. 27-20.

To be able to determine if the unit is fully charged with refrigerant, a sight glass is usually mounted in the liquid line near the condenser.

A dryer is also standard equipment in these systems.

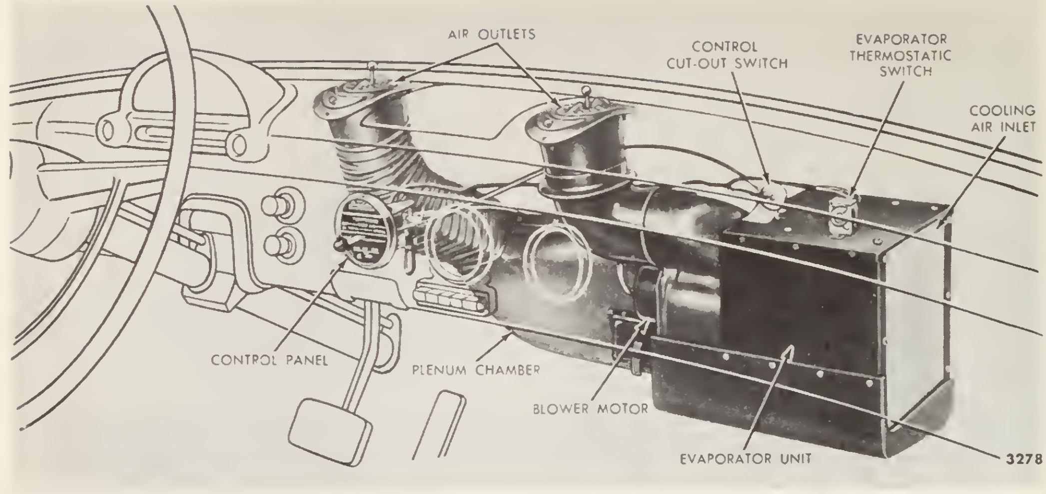
Some systems mount the cooling coils in the trunk of the car, while others mount the coils in a front fender well. A cooling coil, blower, and duct installation mounted under the instrument panel is shown in Fig. 27-20. The heating coil is mounted in the fresh air intake opening and fastens to the fire wall on the dash. Fig. 27-21 shows an instrument panel design for air conditioning systems using a cooling coil mounted up front.

27-12. ELECTRICAL SYSTEM

The electrical system of the automobile air conditioner is unique in that a single wire system is used as the frame of the car serves as the return wire or ground.

The main parts of the electrical system are:

1. Blower or blowers
2. Blower switch

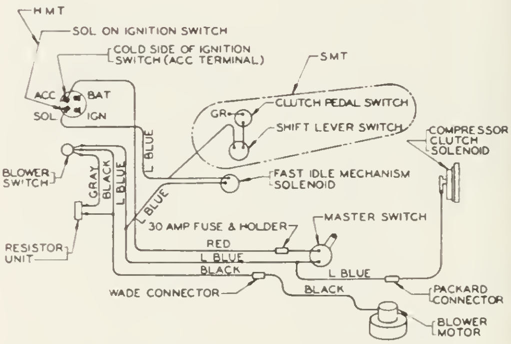


27-20. A cooling coil mounted under the instrument panel.
(Ford Motor Co.)

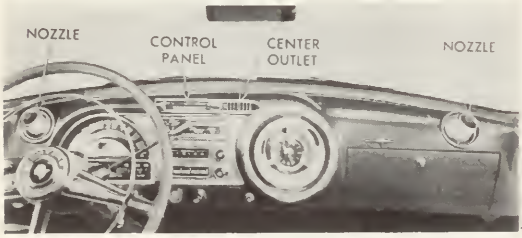
3. Thermostat

A typical wiring diagram is shown in Fig. 27-22. The electrical connections must be kept in excellent condition, because the voltages are low (6-8 Volts or 12 to 14 Volts).

This system uses a fast idle solenoid to permit sufficient comfort cooling when parked or waiting for traffic conditions to clear. The solenoid valve usually opens a vacuum control that automatically adjusts the engine idle speed to about 750 r.p.m. It is wired into the system to function only when the car transmission is in neutral.

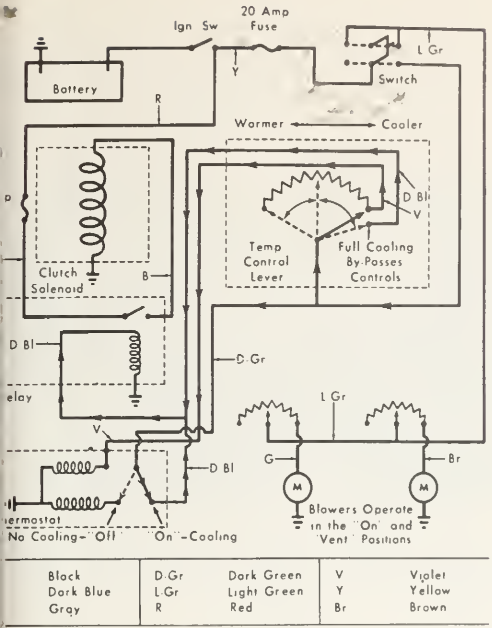


27-22. A wiring diagram of an automobile air conditioning unit that uses a fast idle solenoid and a compressor pulley solenoid clutch.
(Pontiac Motor Div., General Motors Corp.)



27-21. An instrument panel showing air conditioning controls and nozzles. The nozzles are adjustable to direct the flow of cool air where wanted in the car.
(Pontiac Motor Div., General Motors Corp.)

Since the refrigerating mechanism and its controls maintain the cooling coil (evaporator) temperature within certain limits, the amount and degree of cooling within the car is controlled by the amount or rate of air circulation over the cooling coils. This air speed is controlled by the speed of the blowers. Some blowers have two different speed steps, others are controlled by a variable rheostat and a great range of speeds may be provided. Fig. 27-23 shows a wiring diagram for an automobile air conditioning system which uses a solenoid clutch, two blower motors with variable speed rheostats, a thermostat, and a manually operated rheostat in the thermostat circuit.



-23. A wiring diagram of an automobile air conditioning system. The unit has a solenoid clutch, two blower motors with variable rheostats, a thermostat, and manually operated rheostat in the thermostat circuit. (Cadillac Motor Car Div., General Motors Corp.)

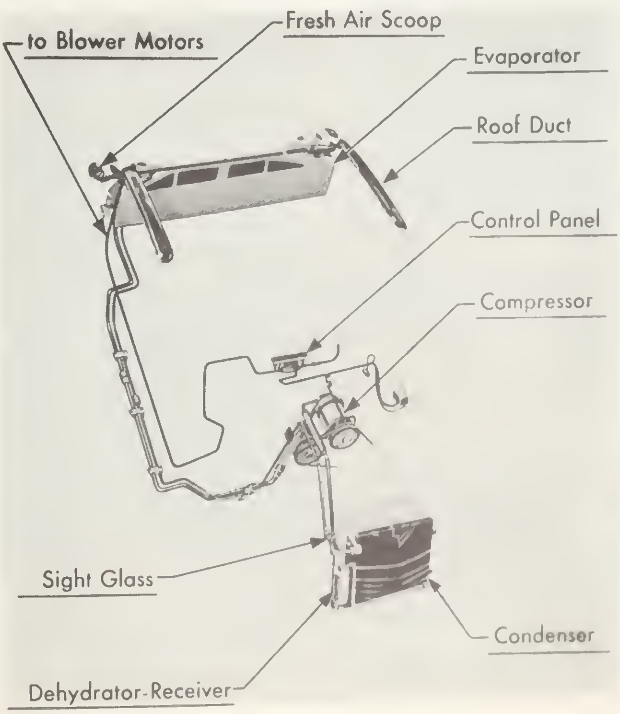
27-13. AIR DISTRIBUTION

The distribution of air within the automobile body offers several unusual problems. The space is confined, the seats present a restriction to the air flow, and the low roof accelerates the possibility of drafts.

A popular method of air distribution is to provide two air duct openings back of the back seat which blow the conditioned air forward and along the ceiling of the body. This air mixes by turbulence with the air in the car and settles over the occupants. See Fig. 27-24. This system will produce noticeable drafts under certain conditions.

An unproved method is to install ducts between the ceiling fabric and the outer shell of the body. Grilles are placed at frequent intervals along these ducts to move conditioned air into the occupied space.

-24. A phantom view of an air conditioning system which has the coils, the blowers, and the filters installed in the trunk immediately behind the rear seat.
(Cadillac Motor Car Div., General Motors Corp.)

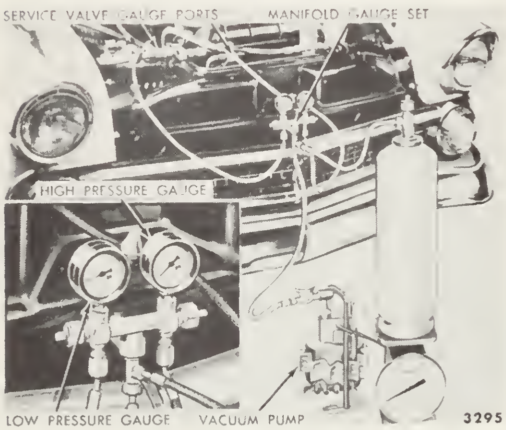


The ducts are made of metal or plastic. Fairly high air velocities are used as the air movement noise is not as critical as it is in an office or residence.

A small controllable duct is usually located between the fan and the outer shell of the body to admit a variable amount of outside air. This duct should be large enough to admit as much as 75% fresh air. Grille covers the duct opening in the car body.

27-14. FANS

Fans used to circulate air are of the radial flow type (squirrel cage or centrifugal type). They are driven by D. C. motors either 6 V. or 12 V. These motors must be serviced periodically.



27-25. An illustration of the correct way to attach a gauge manifold, auxiliary vacuum pump and charging cylinder when charging an automobile air conditioning system.
(Ford Motor Co.)

27-15. FILTERS

All systems use filters. Most of the filters are of the maze-oil impregnated type. These filters average 12 x 12 in. and are 1/2 to 1 in. thick. This size means that the air velocity through the filter is high enough to cause a drop in filter efficiency. It is very important that these filters be replaced frequently (every three months average).

The filters are located at the intake of the blower, and the filter is positioned to clean both the recirculated and the fresh air.

27-16. INSULATION

Most car bodies are at present being sound insulated. A very similar method can also be used to heat insulate the body. Fiber glass, glass wool, or any low K valve non-settling flexible insulation is satisfactory.

The large amount of window area allows considerable heat leakage and also a high sun load. The use of tinted glass reduces the heat load considerably.

To avoid air conditioning the trunk space, insulation is usually placed over the back of the rear seat of the car. This insulation also reduces the noise level of the blower unit.

It is essential that the body of the car be tightly sealed at all joints. The door gaskets must be in good condition. In addition to the usual water tightness test of the car body, it should also be tested for air tightness.

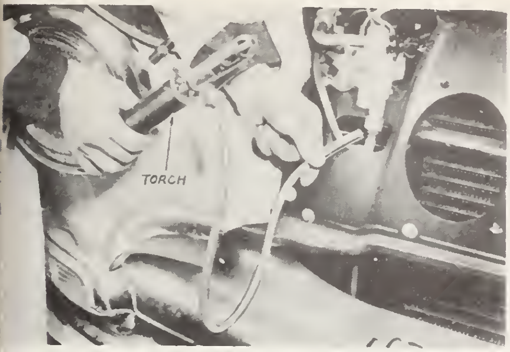
27-17. BUS AIR CONDITIONING

The air conditioning of buses has progressed rapidly. Due to the size of the unit, most of the systems use a gasoline engine with an automatic starting device to drive the compressor. The system is of standard construction except the condensing unit is made as compact as possible, and it is installed in the bus in such a way as to be readily accessible for servicing.

Air cooled condensers are used. Thermostatic expansion valves with finned blower cooling coils are standard. The duct system usually runs in a false ceiling in the bus. The ducts, on

on each side of the bus, have grilles at each passenger seat, controllable by the passenger.

Freon -12 refrigerant is used.



27-26. A picture of the use of a halide torch to detect refrigerant leaks on an automobile air conditioning system.
(Pontiac Motor Div., General Motors Corp.)

27-18. SERVICING AUTOMOBILE AIR CONDITIONING

Servicing the automobile air conditioner is very similar to servicing standard air conditioning systems, commercial systems, and coventional domestic systems. Chapter 11 should be studied thoroughly before attempting to do service work on an automobile refrigerating system.

27-27. The correct way to loosen or tighten a flare unit. The flare nut wrench only should be moved. The open end wrench is to keep the adapter fitting from moving or a leak may be started.
(Pontiac Motor Div., General Motors Corp.)

The method of installing the gauge manifold is similar to procedure described in Chapter 11. Always clean the connections before removing any caps or plugs. The service valve stems must be back seated to seal the gauge openings. The gauge manifold and lines must be absolutely clean and dry both inside and out. Never use a manifold set that has been left open to the air.

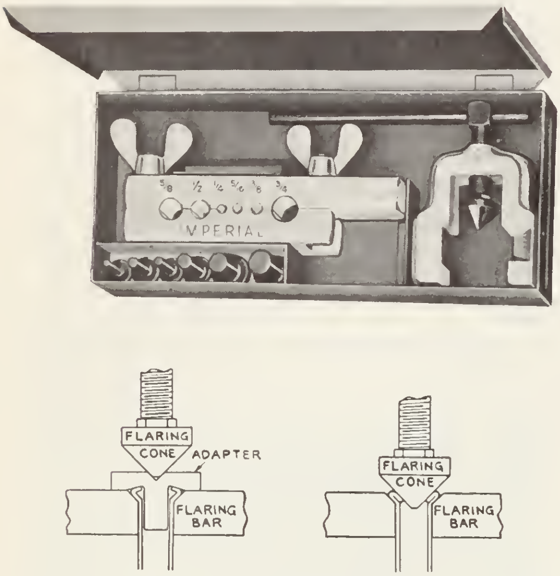
For personal safety, always wear goggles when working on the refrigeration unit or with the cylinders. Avoid breathing any escaped refrigerant. Although the refrigerant is virtually harmless, excluding oxygen is dangerous.

Always attach a gauge manifold to the system before attempting to service it. Compressors are fitted with gauge openings at both the suction service valve and the discharge service valve. After installing an air conditioning system on a car, an auxiliary electric driven compressor should be used to pump the system down and to charge it. The system should be held under a high vacuum for 24 hours at room temperature before charging. Fig. 27-25 illustrates a gauge manifold, vacuum pump and charging cylinder connected to an automobile air conditioning system. Always refer to the manufacturer's service manual for information concerning the amount of refrigerant to be charged with a particular system. Use gauges to check the operating pressures. Low head pressures indicate lack of refrigerant in most cases. Check for leaks thoroughly each time the unit is serviced. See Fig. 27-26.

It is important to remember that good tools and careful use of these tools are very important. Because the refrigerant lines are easily twisted, two wrenches should always be used when loosening or tightening connections, Fig. 27-27.

27-19. DOUBLE FLARE

Most automobile air conditioning systems use flexible refrigerant lines. These lines are fastened to the compressor, condenser, and cooling coil



27-28. A flaring tool used to make the double flare which is the most common one used on automobile air conditioning refrigerant lines.
(Imperial Brass Mfg. Co.)

by means of the double flare joint. Fig. 27-28 shows the tools used to make this flare and the diagrammatic views of the flare being formed.

27-19. REVIEW QUESTIONS

1. Does the heat load increase or decrease as the automobiles speed increases?
2. How are the engine mounted compressors driven?
3. Where is the condenser mounted?
4. What type of line connections are used in these units?
5. Are the systems provided with gauge connections?
6. What kind of a fan motor is usually used?
7. Why is air distribution an unusual problem in the automobile?
8. Do the automobile comfort cooling units have a fresh air intake?
9. What is the maximum capacity of an automobile comfort cooling unit?
10. How much power does the compressor absorb from the engine?
11. Why is slugging more likely in the engine driven compressor unit?
12. What refrigerant controls are used on automobile comfort cooling units?
13. Where is cooling coil usually located?
14. What type filters are used?
15. At what speeds do the engine mounted compressors operate compared to the engine speed?

27-21. OPERATING DATA

A typical automobile air conditioning system will cool an automobile which has been standing in the sun, and is 110°F, down to 85°F in about 10 minutes; then down to 72° in 40 to 60 minutes.

Some systems use 100% fresh air while others use anywhere from no fresh air (all recirculated) to 25% fresh air.

The fans use approximately 200 watts and deliver from 250 to 275 cfm. Air scoops or rams may be used to increase the air flow.

Chapter 28

FROZEN FOOD REFRIGERATORS

Frozen foods refrigeration has grown rapdily in the last few years. This field of quick or fast frozen foods has touched all consumers; it has caused the development of new types of domestic and commercial equipment, and it has presented new problems in design, use, and servicing of frozen food equipment. The use and servicing of domestic and small commercial equipment necessary to quick freeze foods and store these foods will be studied in this chapter.

28-1. HISTORY OF FROZEN FOODS

Man's effort to preserve foods so that no change in flavor, aroma, or texture takes place, dates back many years, but it has been only in the last few years that this dream could actually be accomplished and controlled. At the close of the 18th Century, carcasses of elephants frozen during the Glacial period were discovered and frozen flesh from these animals was still in a good state of preservation. In our own country, the Early Americans froze pies, puddings and meat for future use during the winter. Perishable foods were first frozen commercially in the United States about 1875. By 1890, mechanical refrigeration was adopted to freezing foods but only on large applications of cold storage. These processes are now known as slow frozen foods. A retail line of packaged frozen foods first appeared on the market in Springfield, Mass., in 1930. Its growth has been accelerating ever since. The home freezer and the domestic storage cabinet of the present design dates to just prior to World War II, about 1939. It is now possible with our latest developments to freeze foods at any time and store them for fairly long periods.

28-2. ADVANTAGES OF FROZEN FOODS

The advantages of frozen foods are many and varied. Probably the most important advantage is that it provides the opportunity to preserve a food supply for long periods without seriously affecting the taste, aroma, or texture. Frozen foods allow the consumer to purchase in larger quantities and in season, thereby saving money. It allows the farmer to freeze his surplus foods and to hold them until needed. Frozen foods offer the housewife a method of preparing foods in quantity and ahead of demand, thus actually reducing her work. Christmas dinner may be prepared in October and taken from the freezer Christmas morning for final preparation.

Biologically, no other form of food preservation can compare with fast freezing and then storing at low temperatures (below 0 F.) Research has

indicated that micro-organisms (bacteria, yeasts, and molds) suspended in water, frozen, and stored at freezing temperatures (15 F. or below) are soon killed. Enzymes (catalase and others) which cause food spoilage, are controlled more by low temperatures than by any other form of food preservation. Enzymes tear down tissue during storage periods and their activity is doubled for each 18 F. increase in temperature. They are responsible for the respiring of fruit and vegetables. Blanching does much to minimize enzyme action. Thus for storage at 50 F. the enzyme reaction is theoretically eight times the reaction rate for -4 F. Research indicates that to preserve some foods for long periods (one year or more) the temperatures must be held well below 0 F. (-20 F. or lower for best results).

Meat, poultry, and fish have important collodial changes that must be minimized, and low temperatures are an aid in minimizing this action.

Commercial frozen food must be of good quality, must be carefully prepared for freezing, and it must be kept at low temperatures all the time until it is made ready for consumption.

28-3. MICRO-ORGANISMS

There is some difference of opinion on exactly what happens to foods when they are frozen, and what the scientific explanation of frozen food preservation is. However, it is generally accepted that the freezing destroys or makes dormant most of the micro-organisms. These organisms are extremely small, live cells that exist in all foods. Bacteria are one common form of micro-organisms as are molds and yeast.

28-4. ENZYMES

Enzymes are those miniature particles of matter that exist in all food substances. They are not destroyed by fast freezing, but their increase is minimized by the low temperatures. They seem to serve as catalytic agents or as stimulants of organic change. They are destroyed by pasteurization.

28-5. COLLOIDS

Colloids are peculiar to meats. They are miniature cells in meats, fish, and poultry. If they are abused in any way, such as cell disruption, the food quickly becomes rancid. They seem to be containers or capsules and if this shell is ruptured the food rapidly deteriorates.

28-6. ICE CRYSTAL FORMATION

Fast freezing produces exceedingly small ice crystals, whereas slow freezing gives time for larger crystal growth. The larger the ice crystals the more the cell walls are ruptured, and the more the salts are concentrated.

28-1. A freezer cabinet liner in which the cooling coils are attached directly to the outside of the liner surface. (Kold-Hold Mfg. Co.)

28-7. VEGETABLES

Vegetables that are usually cooked prior to serving are very successfully preserved by fast freezing, provided they are scalded first. Vegetables usually eaten in their raw state cannot as yet be successfully frozen. The

:alding action preserves color, tex-
ıre, and the vitamin content. It min-
nizes the enzyme action.

3-8. FRUITS

Sugar solutions give protection to ·ozen fruits and therefore practically ll are put in a sugar solution prior to ·eezing. These fruits rapidly discolor pon being unfrozen (oxidation) and ıust be consumed immediately (2 hours r less).

3-9. MEATS, FISH, POULTRY

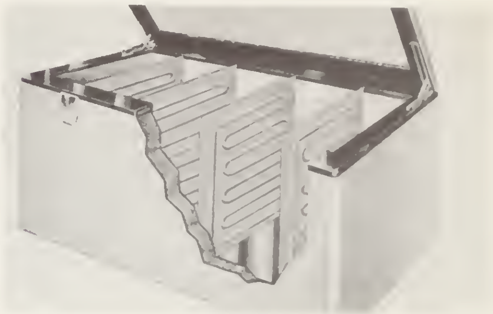
The three major items to guard gainst are drying (freezer burn), ran-idity (oxidation of the fat tissue), and iscoloring (oxidation of other muscle ssues).

3-10. ICE CREAM CABINETS

One of the earliest types of cab-ıets used for home storage of frozen ›od was the ice cream cabinet de-cribed in Paragraph 18-15. This cab-ıet was easily adaptable to frozen ›od storage, because the normal tem-erature range for ice cream storage ; 0 F. to 10 F. There was little need › change any of the construction, and ıly slight changes in motor control ɜttings were needed.

3-11. EARLIER FROZEN FOOD CABINET DESIGNS

When frozen foods started to appear n the market in volume, several com-anies produced special frozen food abinets. One of the first among these as the "Deepfreeze" produced by lotor Products, Inc. This design was a ound cabinet type, opening from the ›p and sold either as a single cabinet r double cabinet type. It was a self-ontained unit with the condensing unit ıilt in the base of the cabinet. The other early makes were very similar to those produced now with the excep-tion of the refrigerant control and the condensing unit. The earlier models used thermostatic controlled expansion valves and open-type condensing units.



28-2. A freezer cabinet using refrigerant plates. (Kold-Hold Mfg. Co.)

28-12. INSULATION

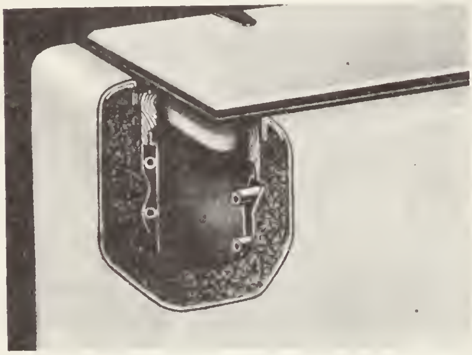
The early frozen food cabinets used about four inches of cork insulation. Insulating materials have varied through the years until now the mater-ial used must not absorb moisture, should reflect some heat, must be fairly inexpensive. As in all refrigeration in-sulations, the properties of being non-settling, low weight, low cost, vermin-proof, moisture-proof and non-hydro-scopic are desirable.

28-13. CABINET CONSTRUCTION

The modern freezer cabinet is con-structed of steel with welded, sealed external shell seams to prevent the entrance of moisture. The outer wrap-per is formed from one piece of sheet steel with a vertical seam located in the back. The bottom is cut and formed and then welded to the sides and ends. Reinforcement plates are frequently fastened to the inside of the outer wall for increasing the rigidity. Several companies use a stamped steel or

angle iron frame. The outside is usually finished with a coating of baked enamel.

The inside liner is made of a plated piece of steel, copper, or aluminum to prevent corrosion. It is usually welded into a moisture tight tank. The tubing for the refrigerant is then attached to the outside of the inner liner. One form of a special liner is shown in Fig. 28-1, where refrigerant passageways are an integral part of the liner. Another method is to use an inner tank without refrigerant surfaces and install refrigerated plates inside the liner. This method is popular in the larger cabinets. Fig. 28-2. In all the cabinets



28-3. The external steel shell is seamless and the inner lining is the cooling coil. Note how the insulation takes up all the space available.
(Kelvinator Div., American Motors Corp.)

the separate liners are assembled, and the space between them and the outer wall of the cabinet, usually 4 to 5 inches, is packed with an insulating material, Fig. 28-3.

The top edge is covered with a plastic or metal strip, and all joints are sealed against moisture. The lid is usually constructed of steel, and the lid is usually made air tight by using soft synthetic rubber gaskets. Some units use an electrically heated resistance wire at the door or lid joint to prevent moisture from freezing the door shut. The condensing unit is generally mounted in the bottom or end of the cabinet, making it a self-contained unit.

28-14. FAST FREEZING TEMPERATURES

The fast freezing temperature depends on the freezing method used and varies from -50 F. to -20 F. The indirect immersion method where the food is placed in containers and then submerged in a brine uses a temperature of approximately -45 F. to -50 F. One method of pumping refrigerant through a tube inserted in poultry freezes them rapidly using a -30 F. to -50 F. temperature. Freezing in a refrigerated room at temperatures only slightly below freezing with only moderate air circulation cannot properly be termed fast freezing, but is known as "sharp" freezing. Higher velocity air blasts (up to 2000 ft./min.) are very successfully used for fast freezing.

28-15. FROZEN FOOD TEMPERATURES

Zero to -10 F. is accepted as the best storage temperatures for most frozen foods. These temperatures are practical for the owner of a freezer who must store all of the various foods in one cabinet. These temperatures are also used in most locker plants. The larger warehouses are equipped to store different foods at different temperatures best adapted to prolong the safe storage period for each different food.

28-16. PREPARATION OF FOOD FOR FREEZING

The most important step in freezing food is to freeze only the best quality foods and to pick those varieties of fruits and vegetables that freeze the best. Freezing will preserve good qual

ity, but it will not make good quality foods out of bad.

28-17. PREPARING VEGETABLES

Vegetables must be thoroughly cleaned and prepared as if they are to be served at once. They must be blanched in boiling hot water for a definite period to preserve natural flavor, texture, color, and food value. Blanching (scalding) is necessary to stop the action of enzymes (Paragraph 28-4). After blanching, cool the food in cold running water or ice water at once and package it in small packages made of moisture-vapor proof materials. There are several kinds of these containers on the market to meet the various needs of the consumer. Freeze the food as soon as possible at low temperatures of -10 F. to -20 F.

28-4. A combination freezer and refrigerator. (Ben-Hur Mfg. Co.)

28-18. PREPARING FRUITS

When freezing fruits, speed is very important as fruit loses flavor and color rapidly. Apples are the only fruit which need blanching while all the others do not. Fruits may be packed in syrup, dry sugar, or without sugar. Pack the fruits in containers of proper size for use later, and then freeze it. Frozen fruits discolor rapidly upon melting and only immediately consumable quantities should be frozen in a package.

28-19. PREPARING MEATS

The freezing of meat is very simple, requiring only that it be cut in pieces suitable for table use, packaged in moisture-vapor proof covering and then frozen. Freeze the meat as quickly as possible to retain the best flavor and quality. Wild game and poultry may be frozen just like beef.

28-20. PREPARING MISCELLANEOUS FOODS

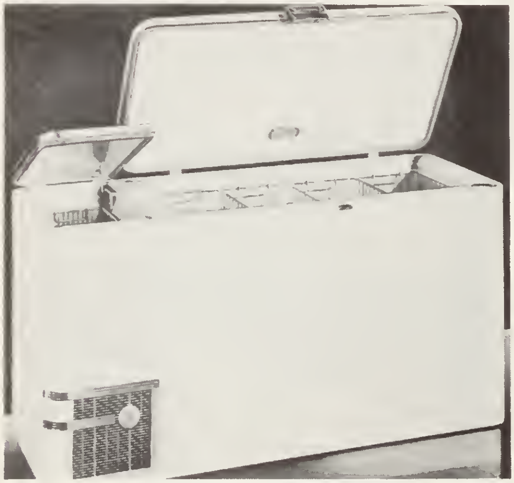
Many other foods may be frozen, and the preparation is simple in most cases. Simply prepare the food as you would for immediate consumption, package in an appropriate container and freeze. The list includes cooked dishes, sauces and dressing, soups, melons, dried fruit, packaged foods, cereals, pies and pastries, bread and rolls, lunches, desserts and salads, and leftovers. Bread may be freshened by freezing it and will stay fresh indefinitely in the freezer.

28-21. STORAGE TIME FOR FROZEN FOODS

The storage time for frozen foods is influenced by many factors such as storage temperature, type of container, condition of food when frozen, and the kind of food. Fruits and vegetables may be stored from season to season with little loss in flavor or color.

28-22. FREEZER BURN

The air in a freezer is relatively dry and unless foods are packed in a moisture-vapor proof container, there will be a steady loss of moisture from the food. After periods of only two or three months light gray spots or areas will appear on the surface of meats and these spots are known as "freezer burn." It is caused by a loss of moisture (drying or dessication). Freezer burn may affect all foods, but the indications of it will vary. Freezer burns may not injure the food value or taste of a food. Proper packaging will eliminate the danger of this condition, particularly if in packaging, all of the air is expelled, and a vapor proof container is used and thoroughly sealed.



28-5. A chest type freezer. The condensing unit is located in the left end.
(The Coolerator Co.)

28-23. FROZEN FOOD SYSTEM CAPACITIES

Frozen food system capacities vary from the small kitchen size storage unit to the large storage warehouse where tons of frozen foods are stored. A small kitchen cabinet unit on the market has a capacity of 3.2 cu. feet and is ideal for the average size kitchen. Most domestic refrigerators have small size frozen foods space in combination with the regular refrigerator storage space. See Fig. 28-4. The latter are known as dual-temperature boxes. The next common size is a 5 or 6 cubic foot cabinet either of the chest or upright type. These cabinets are manufactured for use in the utility room or basement. Other storage and freezing cabinets vary from 6 cubic feet up to 60 cubic feet for farm use. A small locker plant might have as many as 200 or more lockers. Some of the larger ones contain over a thousand.

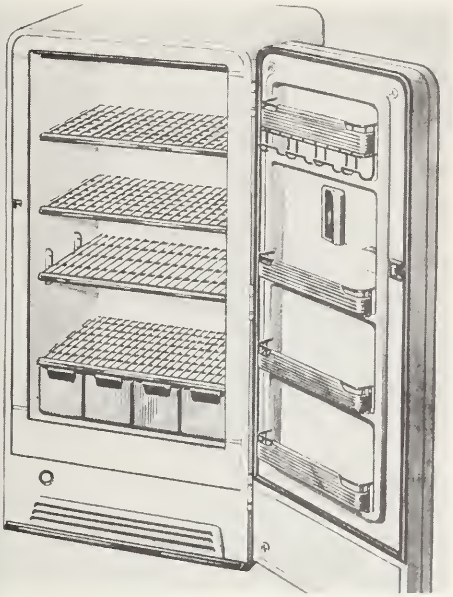
28-24. LIFT TOP CABINETS

The lift top cabinet is known commonly as the chest type. Its big advantage is a minimum loss of cold air when opened. See Fig. 28-5. This type of cabinet is the one described under Cabinet Construction. It is not quite as convenient to put food into or to remove food from, but otherwise it is the preferred cabinet and many of the freezers made up-to-date have been of this construction.

28-25. VERTICAL TYPE CABINETS

The upright type combination freezer and household refrigerator is now in common use. Some of the manufacturers since World War II have made a freezer twin to this type refrigerator cabinet which contains several enclosed sections. These sections are constructed of drawers, or they have fixed shelves with a door in front of each section. These freezers are made for use in the kitchen along with a regular refrigerator. The shelves are usually made of flat refrigerant coils, Fig. 28-6. They are easily accessible but their cost of operation may be a little

higher due to loss of cold air spilling out when the outside door is opened. Also, these upright freezers tend to gather frost more rapidly than the chest type. The vertical freezer cabinet is gaining in popularity in the commercial field, Fig. 28-7.



28-6. An upright frozen foods cabinet. (International Harvester Co.)

28-26. HINGES, LATCHES, DOORS, AND GASKETS

The upright models of home freezers have hardware similar to the standard domestic refrigerator. The chest type, however, has hardware with some special features. The hinges are usually provided with coil springs which will hold the cover in any set position between 5 degrees open, up to 90 degrees open. The springs also counter balance the weight of the door so it may be raised with a minimum of effort. See Fig. 28-8. The latches are usually made of chrome-plated brass and are of fairly heavy design. They are generally provided with a hole through the handle and striker or some other means to enable the cabinet to be locked. The doors are made of pressed steel and are insulated with from 2 to 4

28-7. A commercial design upright food freezer. (Ryan Electronics Inc.)

inches of insulation. They are hermetically sealed at the factory. The common gasket used is the balloon-type live rubber gasket such as used on domestic units.

28-8. A chest type freezer. Note the hardware, the condensing unit space and the location of the controls (Ben Hur Mfg. Co.)

28-27. HERMETIC INSULATION

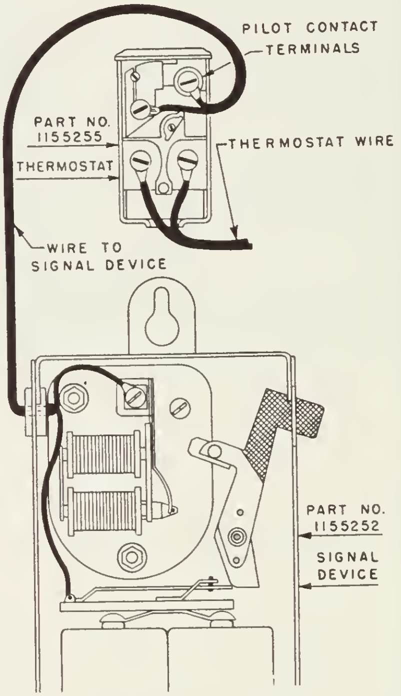
The problem of moisture getting into the insulation (Paragraph 28-12) seems to have been eliminated by the process of hermetically sealing the outer portions of the cabinets and doors against the entry of moisture laden air. There are several methods of accomplishing this result of sealing, but briefly it is a process of welding the cabinets into sealed containers after the insulation has been put in. The welding is done in a place where humidity has been reduced to a minimum. The interior must be dried as thoroughly as possible before it is sealed to eliminate resident or residual moisture as much as possible. If the cabinet is not thoroughly sealed, ice will eventually form in the insulation causing severe sweating and may even destroy the cabinet. It is more important that the outer shell be sealed than the inner shell as any outer shell leak produces an accumulation of moisture in the insulation, while an inner shell leak will remove moisture from the insulation. In servicing freezers, it is sometimes necessary to remove and install all refrigerant, motor control, and thermometer lines which pass through the cabinet insulation. It is very important that such openings be thoroughly sealed with a plastic sealer immediately after the repairs have been completed, otherwise such openings will soon allow moisture to collect in the insulation.

28-28. COOLING COIL DESIGN

The three coil designs widely used are the tank coil (Fig. 28-1), the plate coil (Fig. 28-2), and the blower coil used in larger units. Most of the chest type freezers use the tank or liner type coil. Some of the chest types and all of the upright types use a plate coil, and large units use a combination of plates and blower coils.

28-29. REFRIGERANTS AND REFRIGERANT CONTROLS

Refrigerants for freezers should be capable of giving the desired low temperatures, -10F. to -20 F., with a low side pressure of approximately atmospheric. The high side pressure should not be excessive. The gas volume pumped must be small in order to keep the size of the compressor at a minimum. For instance, if sulphur dioxide were used as a freezer refrigerant,



28-9. A typical freezer alarm system. This is a battery operated unit and is independent of electrical power failure. It must be connected to a thermostat or to a special unit thermostat. The batteries are good for 50 hours or 12 months idle time. It has both a sound and a visible indicator.
(Kelvinator Div., American Motors Corp.)

the compressor would need to be much larger than the compressor now in use.

The two most common refrigerants which meet freezer requirements are Freon -12 and Freon -22. See Paragraph 8-7 and Paragraph 8-9 for characteristics of these refrigerants.

The small modern frozen foods cabinets usually use a capillary tube as a refrigerant control. For a description of this control see Paragraph 5-19. Some units employ a thermostatic expansion valve as the refrigerant control. See Paragraph 5-6 for a discussion of this valve. Older cabinets may be found with a low side float valve, but these are no longer produced. Some experimenting has been done using high side floats.

28-30. MOTOR CONTROLS

Home and farm freezers usually employ a thermostatic motor control designed for the lower temperature setting but otherwise identical to the domestic refrigerator type. These controls are explained in Paragraphs 6-8 and 6-10.

The larger farm freezers and locker plants use a thermostat and solenoid combination to control box temperature and a pressure motor control (see Paragraphs 19-31, 19-32, and 19-41) on the condensing unit. The thermostat in the box or room operates a solenoid valve in the liquid line so that, when the cabinet or room reaches the desired temperature, the refrigerant flow is shut off, this causes the low side pressure to drop and the pressure motor control to stop the condensing unit. When low side pressure has been reduced sufficiently, the pressure motor control on the condensing unit shuts the unit off. A more constant cabinet temperature can be maintained with this type of hook-up.

28-31. ALARM SYSTEMS

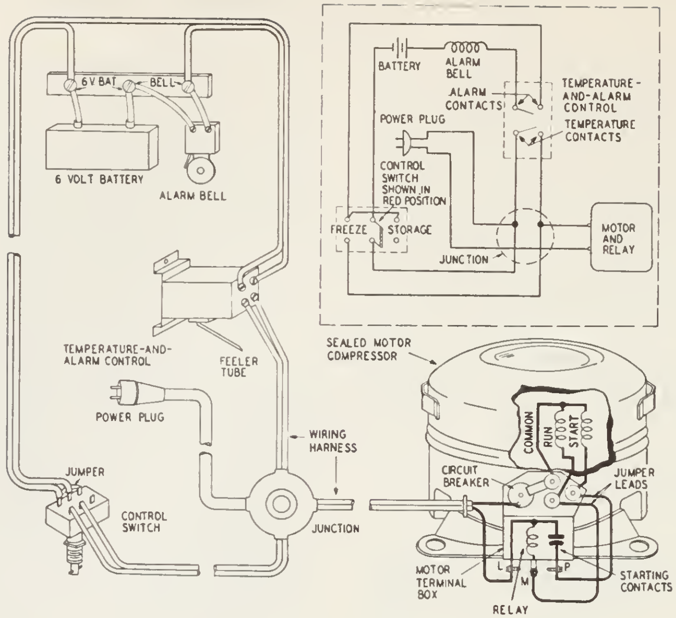
Because a frozen foods cabinet may contain food worth a great deal of money, and a rise in temperature would cause considerable spoilage, some device is usually provided to protect the consumer in case the unit fails. There are several makes of alarm systems on the market, but basically they are all similar. They consist of a control bulb suspended inside the cabinet which is connected to a mechanism that operates a light, a bell, or a buzzer.

A source of electrical power completes the system. The source of power may be batteries, Fig. 28-9, or a transformer may be connected to any other electrical circuit in the house except the unit circuit.

When the freezer temperature rises, it causes the control to close and complete the electrical circuit, which causes the light to operate or the bell or buzzer to ring. The alarm should start to operate when the compartment reaches 15 F. The alarm control bulb should be located near the food that would become warm first. If the type requiring 110 volts is used, it should be connected to a different fused circuit than the one operating the unit. If the battery type is used, the batteries should be checked at frequent intervals to ascertain their charge.

A wiring diagram of a 6-volt alarm system connected into the regular wiring system is shown in Fig. 28-10. The combination thermostat and alarm control will cycle the control, but if the unit will not start or if the temperature continues to rise the alarm circuit is closed. The control switch is used to eliminate the cycling control during freezing operaiions (control is moved to the left). When normal cycling is desired this control switch is moved to the right. If the control switch is left open, it will indicate red.

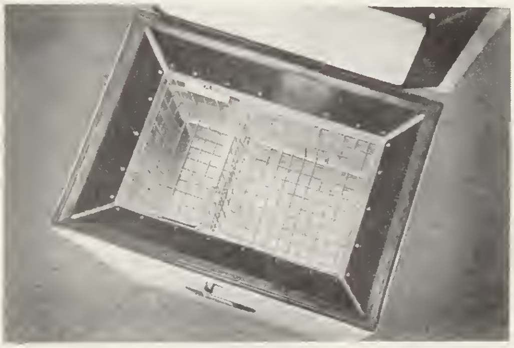
It is important to remember that a well-filled frozen food cabinet will maintain safe temperature for 48 to 72 hours after the unit fails, and also dry ice can be used as the cooling agent until service can be resumed.



28-10. The wiring diagram of a 6 volt alarm system. The thermostat also includes the alarm switch and the alarm bell will ring if for any reason there is an excessive temperature rise.
(Philco Corp.)

28-32. DEFROSTING

Frost will slowly form on the cold walls of a freezer which must be removed when it interferes with the use of the cabinet or the closing of the lid. A freezer normally needs to be defrosted only once or twice a year. Use a wooden paddle or a fiber brush to remove the frost. Be careful not to scratch or otherwise damage the inside surface of the cabinet. When a more complete defrosting job is required or desired, select a day when the food supply in the cabinet is low. Wrap all the food in newspapers or pack it in dry ice, and then proceed to defrost the cabinet by shutting off the power and washing the inside with baking soda and water. The inside of the cabinet must be thoroughly dried before starting the unit. Replace the food only after the cabinet temperature is below 32 F.



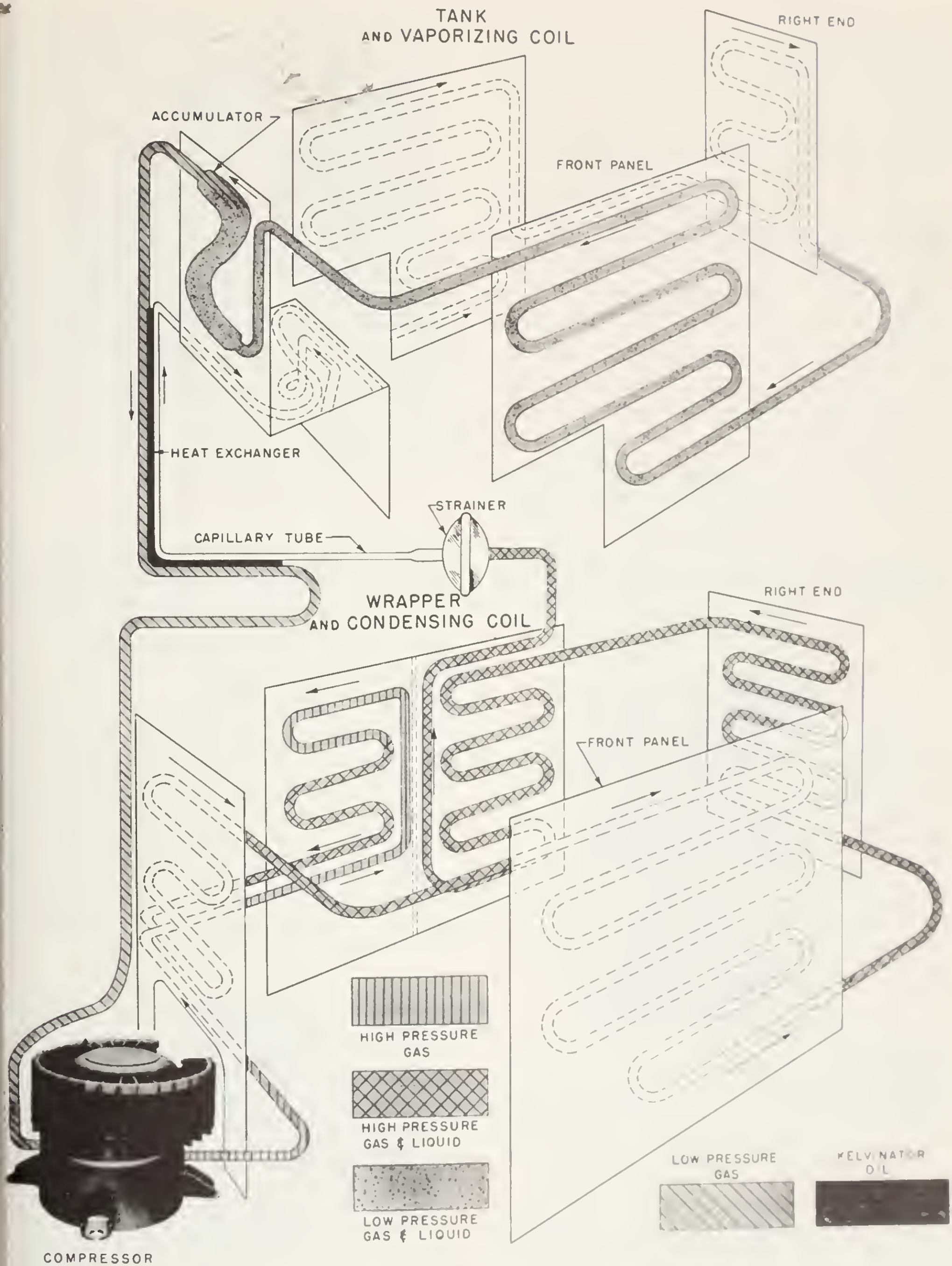
28-11. A wire basket arrangement for a chest type freezer.
(Hotpoint Inc.)

28-33. SECONDARY DOORS

Secondary doors are those doors on each individual inner compartment of an upright type frozen foods cabinet. Such doors prevent the spilling out of cold air from the other compartments and they minimize frost collection. These doors are usually spring operated and are made of metal, glass, or plastic.

28-34. SHELVING

Shelving in a chest type freezer



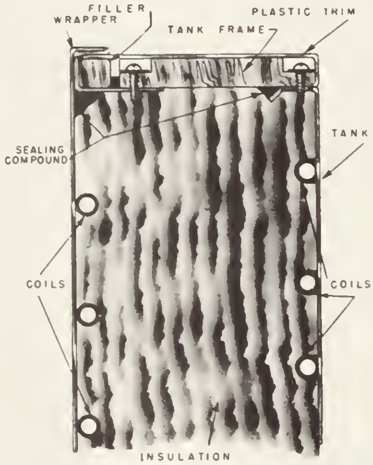
28-12. A freezer cabinet refrigerating unit (condenser arrangement). (Kelvinator Div., American Motors Corp.)

consists of wire baskets at the bottom of the compartment. Fig. 28-11 shows a typical example of the chest type arrangement. Shelving in the upright models consists of from 4 to 6 refrigerated shelves made into individual compartments complete with individual doors. In locker plants tiers of drawers

form the lockers. In most cases the shelving used in freezers is part of the cooling coil.

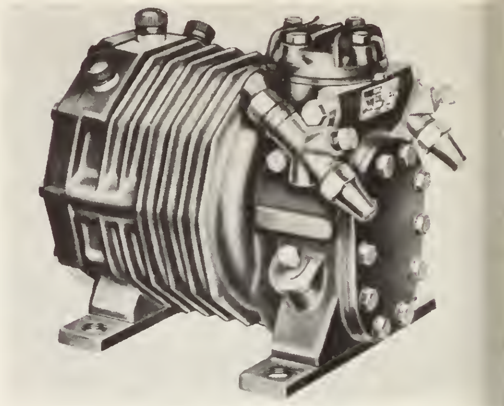
28-35. CONDENSING UNITS

Home and farm freezers employ various types of condensing units. The small home freezer usually has a hermetically sealed condensing unit. For complete information on this type of unit, refer to Chapter 16 and 17. Kelvinator employes a rather unusual condensing unit arrangement as shown in Figs. 28-12 and 28-13. The condenser for this unit is mounted just inside the outside shell and is of the plate type. The larger home freezers use the conventional open type condensing unit. Another type being used



28-13. The wall construction of the Kelvinator freezer showing the condenser coils (left side) against the outer wall of the cabinet.
(Kelvinator Div., American Motors Corp.)

on some freezers is a semi-hermetic unit. One of these is the Copelamatic shown in Fig. 28-14. The condensing unit of a frozen food unit must be about 50% larger for the same volume cabinet as the typical domestic refrigerator. This increase in size is mainly due to the low suction pressure causing the suction gas to occupy more volume and



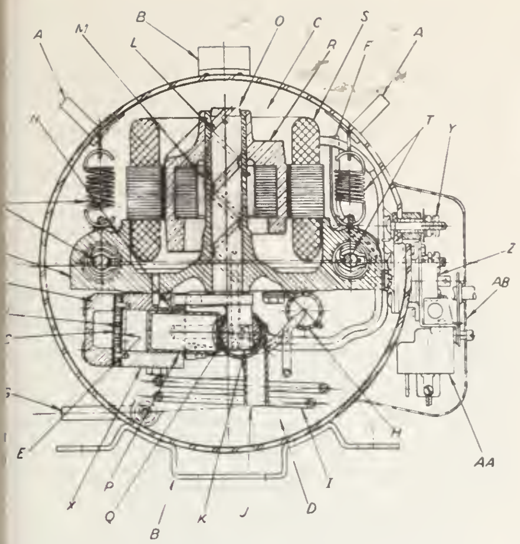
28-14. A sealed compressor unit for freezers. This unit is a bolted assembly. Note the service valves and motor terminals.
(Copeland Refrigeration Corp.)

the greater difference between the suction pressure and the condenser pressure. Fig. 28-15 illustrates a smaller unit using a static condenser.

28-36. COMPRESSORS

Freezers are manufactured using the reciprocating and rotary compressors. Some models have sealed compressors; others use open-type compressors. A small hermetic compressor is shown in Fig. 28-16. Note the motor protection devices and the start

28-15. A sealed unit with a natural convection condenser.
(Tecumseh Products Co.)



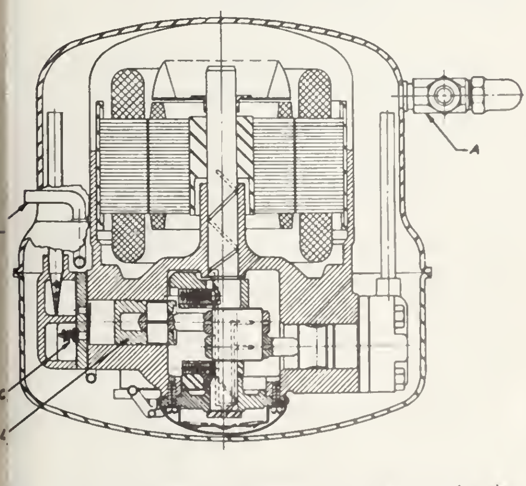
!8-16. The internal design of a very compact compressor: S. Stator; R. Rotor; O. Crankshaft; X. Cylinder; G. Condenser connection; A. Suction line connections. (Tecumseh Products Co.)

.ng relay on the right (AA, AB, and Z). A hermetic compressor used in larger systems is shown in Fig. 28-17. For information on various compressors, see Paragraph 4-17 for rotary; Paragraph 4-4 for reciprocating types.

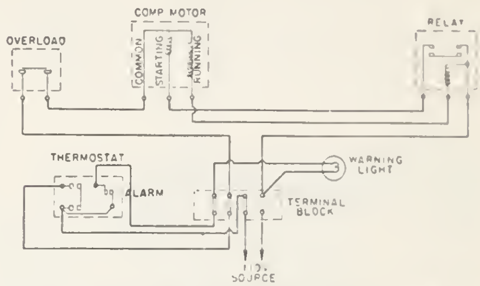
28-37. MOTORS

The types of motors used on freezers can be divided into two groups. The sealed-type condensing unit uses an induction motor with a starting winding operated by a relay. For more information on induction motors consult Chapter 7.

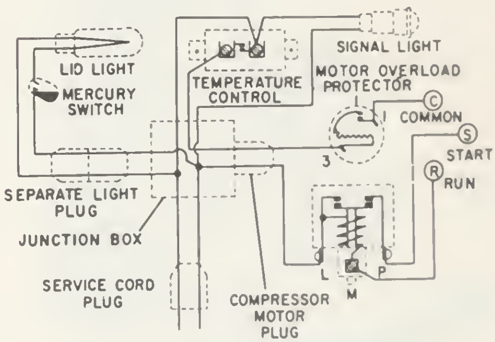
A small fan motor is sometimes used to increase the air flow over the condenser, and it is also of the induction type.



28-17. A high capacity hermetic compressor unit. A. Suction service valve; B. Discharge tube; C. Exhaust valve; D. Piston. (Tecumseh Products Company)



28-18. A wiring diagram of a frozen foods refrigerating unit. Note the relay, terminal block, and the warning device with the special thermostat. (Carrier Corp.)

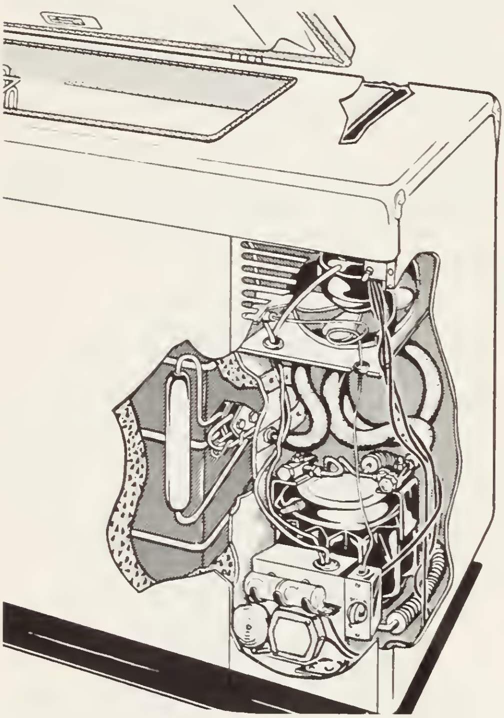


28-19. A wiring diagram of a frozen foods unit and cabinet. A mercury switch completes the lid light circuit when the lid is lifted. The signal light is energized while the unit is running. (Franklin Mfg. Co.)

The other type of motor widely used on conventional condensing units is the capacitator type. For more information on this motor, also consult Chapter 7. Fig. 28-18 illustrates a complete wiring diagram for a hermetic type frozen food cabinet. Note how the warning light is energized by

a thermostat built into the same device that controls the cycling of the unit.

A complete wiring diagram for a chest type frozen foods unit is shown in Fig. 28-19. Many of the cabinets use electrical heating elements to prevent sweating and freezing at the door gasket joints. Fig. 28-20 illustrates a wiring diagram showing a drier coil (heater), an alarm system, the motor circuit, etc.



28-20. Chest type frozen foods cabinet equipped with hermetic unit, forced convection condenser and service valves.
(Frigidaire Div., General Motors Corp.)

28-38. CONDENSERS

The condensers used on freezers are the same as those found on domestic refrigerators. This includes the use of the finned condenser, both forced and natural convection, and the plate condenser. On one model mentioned earlier, Paragraph 28-35, the condenser is mounted just inside the outside shell while others are placed with the condensing unit. On larger units water-cooled condensers are used, Chapter 19.

28-39. RECEIVERS

On many freezing units, particularly the older models, the conventional liquid receiver is used. The small home freezers today employing a capillary tube control do not have a separate part for a receiver, but the lower section of the condenser serves the same purpose.

It should be noted that in freezers using the capillary tube refrigerant control the greater portion of the liquid refrigerant will remain in the cooling coils during both the running and off part of the cycle.

28-40. BELTS

Many older models and some recent model condensing units use belts. For more complete information on belts, alignment and care, consult Chapter 7.

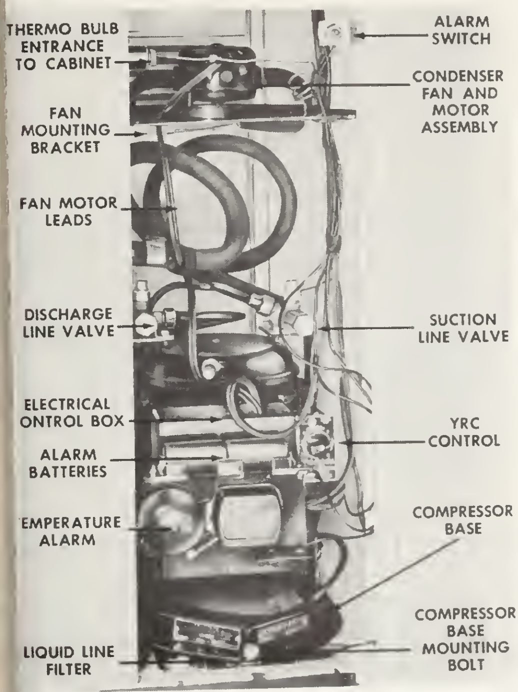
28-41. LIQUID LINES

The liquid lines are now practically all connected by silver brazing. On capillary units, the liquid line is the capillary tube. These liquid lines are generally soldered to the suction line for two to four feet for heat exchange, and they must be carefully mounted to prevent vibration rattles.

28-42. SUCTION LINES

Because of the low temperatures, and because some refrigerants tend to frost back, it is sometimes necessary to use heat exchangers to warm the return gas and it may also be necessary to insulate the return line with sponge

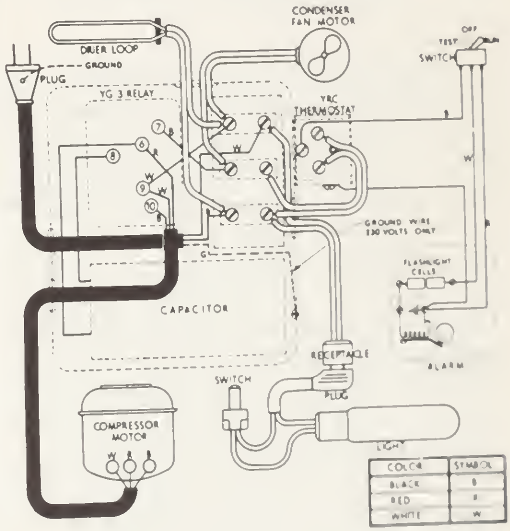
rubber to prevent sweating and dripping. Mount the suction line carefully to prevent vibration rattles. The suction line fittings are usually soldered. The openings into the cabinet where the lines must go to reach the cooling unit must be made air tight with some mastic tape or ice will accumulate, Fig. 28-21.



28-21. Details of condensing unit compartment for frozen foods cabinet shown in Fig. 28-20. (Frigidaire Div., General Motors Corp.)

28-43. STARTING THE UNITS

The first step is to see that the freezer has been located properly for free air circulation and that sufficient space for opening of doors or lids is provided. The next step is to check the freezer electrical circuit. This circuit should be a separate circuit starting at the main entrance panel, and it should have no other appliances or switches connected to it. This precaution is required by the electrical code in many sections and should be followed in all cases, as any interruption of electric current might become very costly to the owner. To actually start the unit, plug it in to the outlet plug and turn the thermostat control knob to the "On" position. There are no valves to be opened on the smaller home freezers using sealed units. On other freezers, check the starting instructions before turning the unit on. In all cases remove the shipping bolts that are used to hold the condensing unit



28-22. Complete freezer wiring diagram. This system incorporates condenser fan motor, alarm system, automatic light, and a drierloop. (Frigidaire Div., General Motors Corp.)

during shipment. Carefully file away the warranty and operating instructions, as these may be needed sometime during the 5 to 10 year warranty.

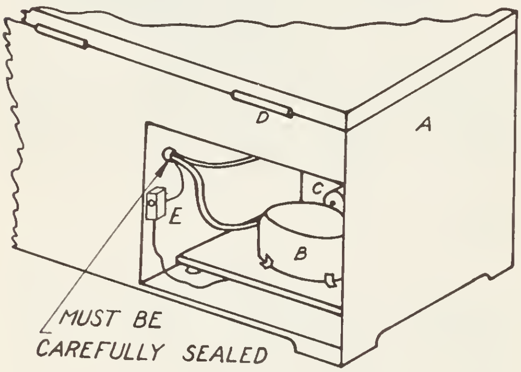
28-44. CYCLING

Cycling time on home and farm freezers can not be stated in any definite limits of time. Cycling time will vary depending on the amount of storage space being used, on the outside temperature of the box, on the condition of compressor, etc. Putting in food

to be frozen will also affect cycling time a great deal. In general, it can be said that it will run about one-third of the time. In other words it may run 5 minutes and be off 10 minutes, or it may run 1 hour and be off 2 hours. The important point here is that any unusual change in cycling time should be investigated immediately, as it may indicate trouble developing in the system.

28-45. SHUTTING DOWN FROZEN FOOD UNITS

When shutting down the frozen food unit, special precautions should be taken to prevent rusting and to eliminate odors. After the electrical plug has been removed or the current shut off by a switch, allow several hours for the unit to completely defrost. When the defrosting is completed, remove all the excess water and wash the inside of the cabinet with a solution of baking soda and water. Thoroughly dry the inside of the box. A portable heater set inside the cabinet will speed up this step. Leave the doors or lids ajar slightly to allow circulation of air during the shut down period.



28-23. Sealing the cabinet openings. A. Cabinet; B. Compressor; C. Condenser; D. Balanced door hinge; E. Motor control.

28-46. UNIT TROUBLES

Home freezers are subject to all the trouble that may occur in domestic refrigerators (Chapters 11 and 17) and in addition, due to the lower temperature involved, there are a few new troubles. These include (a) ice formation, (b) moisture in the system, and (c) wax separation in the system. These will be covered in more detail in the following paragraphs.

28-47. ICE ACCUMULATION

Ice formation is a condition which will interfere with (a) the operation of the lid or doors, and (b) the running time and temperature of the unit if sufficient accumulation of ice occurs inside the box. Ice forming between the outside and inside liners of the cabinet in the insulation will cause considerable trouble.

The first condition mentioned above is usually caused by a leaky gasket seal. It may be that the seal has lost its life or is broken; in either case the rubber gasket should be replaced. The trouble may be that the hinges or lock needs adjusting. A flat slip of paper inserted between the door and the cabinet should be held tightly when the lid is closed. If this paper pulls out easily, it means the gasket is not tight, and the hardware must be adjusted and the gasket replaced.

An excessive accumulation of ice in the food storage space acts as insulation and may result in poor cooling down time for foods placed in the cabinet.

Ice accumulation in the insulation is a more serious trouble as it indicates an air leak in the exterior cabinet seal allowing warm air to enter this space. The warm air being cooled on contact with the inner liner gives up some of its moisture in the form of ice in the insulation or on the liner. If

this condition is not corrected, enough ice will eventually build up to buckle the sides of the cabinet.

The only way to remedy this trouble is to remove the dry insulation, dry out the space between the liners, repack with dry insulation, and completely seal the two liners against the entrance of air.

This ice accumulation is one of the main troubles occurring with improperly or carelessly constructed units; it also reduces the insulating ability of the cabinet, and the unit will run considerably more.

An accumulation of ice in the insulation of a freezer will generally be indicated by a cold spot on the outside surface of the freezer or by condensation on the outside surface. Also, if the insulation is badly iced up, the condensing unit may run continually. Iced up insulation will melt and drain when the freezer is shut down and allowed to warm up for several days.

28-48. WAX IN THE SYSTEM

All oils including those used in refrigeration systems contain a small amount of wax. This presence of wax has presented a real problem to refrigeration engineers ever since the earliest low temperature cabinets were built. A small amount of oil circulates with the refrigerant, and due to the sudden expansion occurring at the orifice of the refrigerant control and the low temperature and pressure at which this expansion occurs, a small amount of wax is separated from the oil and collects in the refrigerant control orifice. It accumulates over a period of time until the valve becomes restricted or clogged completely. The only remedy after this clogging has occurred, is to remove the valve and clean it or to replace the valve. When servicing frozen foods equipment, be sure to use a thoroughly de-waxed oil.

For ordinary household and commercial refrigeration and in conditioning service most refrigerant oils are satisfactory. However, for service in food freezers, a completely de-waxed oil is necessary.

Moisture in the system will form in the refrigerant control at the point of expansion. This moisture may be effectively removed by inserting a dehydrator in the liquid line.

28-49. INEFFICIENT CONDENSING UNIT

The efficiency of the condensing unit depends on several factors. Each one must be considered to determine which one is causing the unit to be inefficient. The compressor is the most important factor, and any one of several things may cause it to be inefficient. The most frequent reason is leaking compressor valves. A slipping belt may also cause a compressor to be inefficient. Worn pistons, piston rings (if used), and/or a worn cylinder bore may all cause inefficient pumping.

The next most important factor is the condenser and air flow over the condenser. The condenser surface must be clean for highest efficiency, and enough clearance must be allowed around the cabinet for free movement of the air that passes over the condenser.

Another factor in an inefficient unit may be a faulty motor. All the various parts of the condensing unit must be checked carefully and put in perfect condition to get top efficiency from the unit.

28-50. SERVICING FROZEN FOOD UNIT

For servicing the open type condensing units, refer to Chapter 11. For servicing hermetic units, refer to Chapter 17. The procedures vary great-

ly due to the differences in cabinet design and construction. However, some of the more common service pointers are as follows: during the overhaul or exchange of the refrigerating unit, it is essential that the frozen foods be kept refrigerated. These foods will stay at a safe temperature in the cabinet for 48 to 72 hours after the unit is shut off. The service man can make a temporary frozen foods box from any available container and use dry ice to keep the food frozen. Rumpled newspaper makes a good temporary insulation.

When dismantling a cabinet the tar (hydrolene) seals may be easily and neatly removed with a hot knife. Use this tar generously when resealing. The tar should be carefully melted in a double boiler with water in the outside boiler. The melting of the tar is an extremely dangerous operation so it is necessary to be very cautious.

In case the unit has a bad thermostat, it is safe to connect the unit directly so that it runs continuously until a new thermostat can be obtained and installed. In this latter case, the owner can be instructed to shut the unit off for an hour every other hour or two hours, or allow it to run continuously as this will do no harm and will assure ample refrigeration.

Whenever it is suspected that there is moisture or wax clogging the refrigerant control, it is very important to keep the ice or wax locked in the control until the control is removed. This precaution will enable the service man to remove the wax or moisture from the system permanently. The simplest way to keep the wax or ice in the control is to pack the valve in dry ice until the valve can be removed from the system. The valve may then be warmed and the moisture or wax removed.

28-51. REVIEW QUESTIONS

1. List three advantages of frozen foods.
2. What was the date on which a retail line of frozen foods first appeared on the American market?
3. What is caused by the action of enzymes?
4. What type of insulation is used in modern freezers?
5. List the steps for preparing vegetables for freezing.
6. What is meant by hermetic insulation?
7. What two refrigerant control systems are commonly found on frozen food cabinets today?
8. How often should a freezer be defrosted?
9. A 6 cubic feet home freezer would probably have what kind of condensing unit?
10. What is meant by freezer burn?
11. What is highest temperature at which beef might be stored for 6 months?
12. What is the best temperature range for any home freezer?
13. Most frozen foods cabinets use what kind of motor control?
14. Why is it important to have an open space around a freezer especially near the condenser?
15. Which condition of ice accumulation mentioned in this chapter is the most serious?
16. How does wax get in a refrigeration system?
17. Give two (2) ways moisture may enter a system.
18. What may be used to remove moisture from a refrigeration unit?
19. What service jobs can be performed on a hermetic unit?

Chapter 29

TECHNICAL CHARACTERISTICS

29-1. VORTEX TUBE

An interesting device that produces both cold and heat is the vortex tube.

Two tubes are connected at right angles to each other. One tube has a jet which directs air tangential to the inner surface of the other tube, Fig. 29-1. When room temperature air at 150 psig is introduced at A, the temperatures of the exhaust air at B and C may be as much as 200 F. different. The temperatures at C have been lowered to -36 F. under certain conditions.

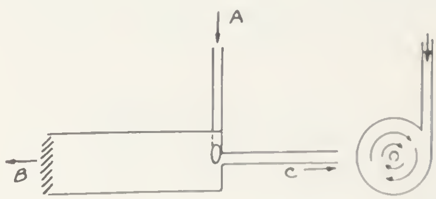
29-2. ELECTROLYTIC MOTOR STARTING CAPACITOR *

Electric motor driven equipment is usually powered by single phase fractional horse power alternating current motors. The development and perfection of economical high capacity electrolytic AC capacitors has made possible the practical use of electrically efficient high starting torque capacitor motors.

The capacity used for any motor is chosen to give the maximum starting torque. This is determined by the motor manufacturer. In the field, when the replacement of the capacitor is necessary, the replacement unit should have the same capacity as the original unit. If the identification marks on the original unit are lost, the service man must determine the proper sized unit to be used.

*Courtesy of Aerovox Corp.

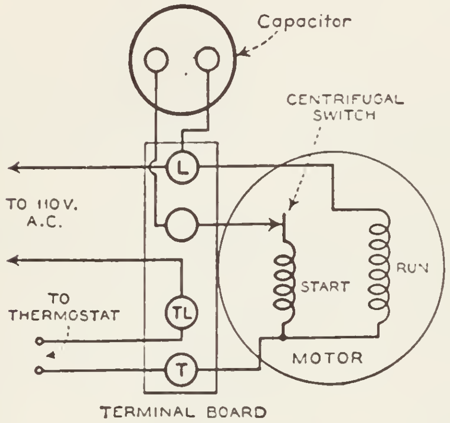
The circuit diagram of a typical capacitor-start single-phase induction motor is shown in Fig. 29-2. The purpose of the capacitor is to produce a current in the starting winding which will produce a magnetic field that will combine with the main winding and produce a high starting torque. The current that flows in the starting winding is determined by the voltage of the line and the design of the starting winding.



29-1. Producing refrigeration with the Vortex tube.

If various size capacitors are used on a motor and the starting torque and voltage across the capacitor are measured, a curve similar to that of Fig. 29-3 is obtained. The torque rises rapidly, and, after reaching its maximum value, slowly decreases. In the vicinity of the maximum value a fairly large change in capacity produces a

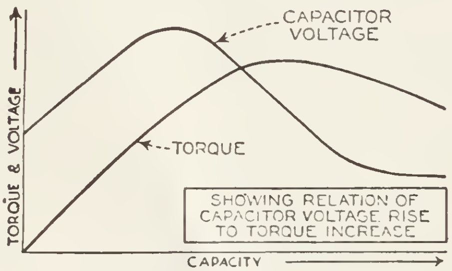
relatively small change in torque. This is advantageous, as the relatively wide tolerance in the capacity of the capacitor keeps the cost of the unit down. The voltage across the capacitor reaches its maximum value before the torque and then starts to decrease. Since the voltage across the capacitor is determined by the design of the starting winding and the line voltage, the voltage across the capacitor is a



29-2. Wiring diagram of condenser-start motor. (Aerovox Corp.)

good indication of the proper size capacitor.

Standard practice today calls for a maximum capacitor voltage of 138 volts



29-3. Capacitor voltage rise to Torque increase. (Aerovox Corp.)

during the starting period for a 120-volt motor. This voltage lasts for a very short period of time, usually less than one second. Higher voltages, such as occur with undersize capacitors, will decrease the life of the capacitor markedly. The use of undersize capacitors will not prevent the motor from starting, but it will increase the starting time and the voltage across the capacitor.

Since electrolytic motor-starting units are not continuous-duty units, the excessive voltages and starting period that occur with improper capacitors decrease the life of the unit. If the capacitor is too small, the torque produced may be insufficient to bring the motor speed up to the point at which the centrifugal switch disconnects the capacitor from the line. Under such conditions the capacitor soon fails by drying out. The starting period should not exceed three seconds in a properly functioning motor.

These capacitors are made for intermittent duty only, and are usually damaged by the failure of the associated equipment. IT IS IMPORTANT, THEREFORE, TO DETERMINE AND ELIMINATE THE CAUSE OF CAPACITOR FAILURE BEFORE REPLACEMENT. In addition, the replacement capacitor should be of proper capacity and voltage rating. The use of a wrong capacitor will usually result in rapid failure. For that reason, AC electroyltic capacitors are guaranteed as follows:

I. 110-volt Capacitors

(a) Starts-Heavy-Duty Capacitors

(standard foil and papers), not more than 20 starts per hour, each start not over 1 second duration (except that not over 100 times per year the capacitor may be on the line for periods not exceeding 10 seconds maximum). Ultra-Compact Capacitors (etched foil and reduced papers) not more than 20 starts per hour, each start not over 1 second

duration (except that not over 50 times per year the capacitor may be on line for periods not exceeding 10 seconds maximum).

(b) Voltage not in excess of 125% of the rated voltage during any service period.

(c) Ambient temperature not to exceed 130 F.

(d) Damage - Capacitor shall not have been damaged after shipment by manufacturer.

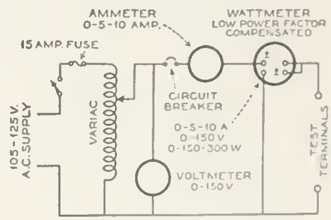
(e) Motor defects - Capacitor shall not have been subjected to abnormal operating conditions resulting from motor and associated defects such as: (1) defective or dry bearings; (2) sticky compressor; (3) tight belt; (4) defective centrifugal switch or relay; (5) improper adjustment of thermostat or refrigerator valves. Before applying capacitor, always check (a) centrifugal switch or relay; (b) easy turning of motor and compressor; (c) thermostat and valves, as a prerequisite of the guarantee.

II. All other Voltages

Same as for 110-volt capacitors except that the voltage applied to the units during any service period may not exceed 10% of the rating.

It is recommended that the service man should check the following points before leaving the job:

1. Measure the voltage across the capacitor during the starting period. It should not exceed 138 volts for 110-volt capacitors. For other voltage ratings, it should not exceed 110% of the nominal rating. If the voltage across the capacitor is higher than the limiting value given, it usually indicates a capacitor of too low capacity.
2. Time the duration and frequency of the starting period. It should not exceed the limits given in the guarantee. If the start takes too long, either the capacity of the unit is incorrect - too high or too low - or the associated equipment is defective. Too frequent starts (over 20 per hour) should not be allowed. It usually indicates some defect in the control equipment.
3. Measure the temperature of the capacitor motor compartment. It should not exceed 130 F.
4. The container of the capacitor should be insulated from ground.



29-4. Circuit diagram for measurement of capacity and power factor by the Ammeter-Voltmeter-Wattmeter method.
(Aerovox Corp.)

Attention to these factors will generally result in a satisfactory job.

Electrolytic motor starting capacitors may be tested for their capacity and power factor by connecting them to AC of proper voltage, and reading the current and wattage of the unit, Fig. 29-4. The capacity of the unit is then approximately

$$C\ MFD = \frac{159{,}300\ I}{f\ E}$$

$$\frac{\text{amperes}}{\text{cycles p. sec. x v.}}$$

Fig. 29-5 has been compiled to facilitate computation of capacities at various voltages and frequencies.

The power factor of the capacitor is the measure of the loss of power in it. Capacitors of high power factor do not give as high a starting torque for a given capacity as those with a low power factor. For the same torque higher capacity should be used for units with high power factor. Capacitors with a very low power factor may be readily made at a sacrifice of stability and life. As a result, a compromise between all the factors involved produces the best overall performance.

	Any voltage E	110 volts	220 volts
Any freq.	$159{,}300 \frac{I}{fE}$	$144.8 \frac{I}{f}$	$72.4 \frac{I}{f}$
25 cycles	$6368 \frac{I}{E}$	57.9 I	28.9 I
60 cycles	$2653 \frac{I}{E}$	24.1 I	12.06 I

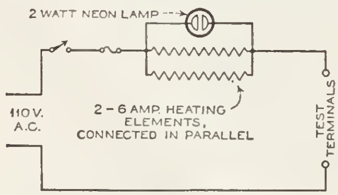
29-5. Capacity in microfarads of electrolytic motor starting capacitors. (Aerovox Corp.)

The value of power factor is given by the expression:

$$\text{Power Factor } \% = \frac{W}{EI} \times 100$$

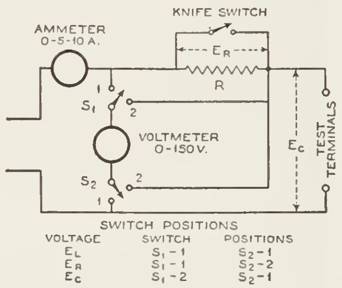
For the usual requirements in service the wattmeter used should be capable of carrying about 10 amperes with a full scale of 150 watts. Such wattmeters are known as low power factor wattmeters and are generally specially made to order.

Since the capacity of the unit is by far more critical than its power factor for satisfactory service, for most purposes the use of a voltmeter and an ammeter is sufficient.



29-6. A.C. circuit for testing capacitor shorts. (Aerovox Corp.)

If a circuit breaker is not available, the capacitor should first be tested for a short. This can be done in several ways. The easiest method is to test the unit on D.C. if a source is available. The capacitor is connected in series with a 100-watt lamp across a 120-volt D.C. line. The lamp will light to full brilliancy when a shorted unit is connected across the line. A capacitor having high leakage will cause the lamp to glow. This test for leakage has very little meaning, as any leakage that will cause a 100-watt lamp to glow is much too great to be tolerated. The 100-watt lamp can be replaced with a 20-watt lamp to give a better indication of leakage. A short can be determined on A.C. with the circuit shown in Fig. 29-6. The neon lamp will light up when a shorted capacitor is tested.



29-7. A circuit used to determine capacitor sizes. (Aerovox Corp.)

Another method of testing a capacitor for power factor does not require a watt-meter but entails considerably more calculation. The capacitance is found, as before, from the current and voltage readings. To find the power factor, the effective or equivalent series resistance of the capacitor is found by the following method: The capacitor is connected in the circuit of Fig. 29-7, and a reading of the current and voltage taken with the knife switch open (E_1 and I_1). If the capacitor is not shorted, the knife switch is

closed and another reading of the current and voltage taken (E_2 and I_2).

The capacitance is found from the second set of readings. To find the equivalent series resistance use is made of the following equation:

$$R_e = \frac{\frac{E_1}{I_1} - \frac{E_2}{I_2} - R^2}{2R}$$

E_1 and I_1 are the readings with the switch open and E_2 and I_2 are the readings with the switch closed. The power factor of the capacitor is then given by the equation

$$\text{PERCENT P.F.} = \frac{R_e}{\frac{E_2}{I_2}} \times 100$$

No simple graph or chart can be made for the calculation of the first equation. If R is fixed, a family of curves can be computed and used for a more rapid calculation of the resistance but this does not save much time.

For the average sized motor starting capacitor a resistance of 20 ohms is a satisfactory value. The exact value of the resistance is not necessary as the voltage drop across it can be found. The circuit can be so arranged as shown in Fig. 29-7, so that by pressing a series of 3 buttons the voltmeter can be connected across the resistor, the capacitor and the line in any order desired. The current will be read on the ammeter as before.

The equivalent series resistance is

$$R_e = \frac{\frac{E_1^{\,2} - E_R^{\,2}}{I_1^{\,2}} - \frac{E_2}{I_2}^{2}}{2\frac{E_R}{I_1}}$$

E_1 and I_1 taken with switch open

E_2 and I_2 taken with switch closed

E_R is voltage across R

With this sequence of measurements it is not necessary to make a separate short circuit test as the first reading, with the knife switch open, will be sufficient to indicate a shorted capacitor. When a 20-ohm series resistor is used, the current will be equal to the voltage divided by the 20 ohms if the capacitor is short circuited. Thus, if a 150-mfd. capacitor is being tested on a 120-volt line, the ammeter will read 4.5 amperes for a good unit and 6 amperes for a shorted unit. If the unit is found to be good the readings of current and voltage are recorded and the knife switch closed. The readings of current and voltage are again recorded and the computations performed. A sample computation is given below.

E_1 = 120 volts	I_1 = 4.0 amperes
E_R = 80 volts	E_2 = 120 volts
E_C = 85.6 volts	I_2 = 5.6 amperes

To find the power factor the first and second sets of readings are used.

$$R_e = \frac{\frac{(120)^2 - (80)^2}{4^2} - \frac{(120)^2}{(5.6)}}{2\,\frac{(80)}{(4)}}$$

$$= \frac{\frac{14400 - 6400}{16} - \frac{14400}{31.6}}{2 \times 20}$$

$$= \frac{\frac{8000}{16} - \frac{14400}{31.6}}{40}$$

$$= \frac{500 - 460}{40}$$

$$R_e = \frac{40}{40} = 1.0 \text{ ohm}$$

The power factor of this capacitor is then found from equation

$$\text{PERCENT P.F.} = \frac{R_e \times 100}{\frac{E_2}{I_2}} = \frac{1 \times 100}{\frac{120}{5.6}}$$

$$= \frac{1}{21.4} \times 100 = 4.7 \text{ PERCENT}$$

Two methods are in use to designate the capacity of capacitors; either their nominal value is given or the limits of capacity are listed. For the first case, the usual tolerance employed by most motor manufacturers is minus 10 plus 20%. The second method fixes the lower limit by the value given. The upper limit, however, is generally 15% greater than the figure listed for the range. Frequently superior performance is obtained in such cases with capacitors of somewhat higher capacity.

Fig. 29-8 lists the capacitors usually used for various sizes and types of capacitor start motors.

Some capacitor-start motors may require capacitors other than those listed and if there is any question as to the correct rating of the capacitor, the exact value can be determined by the use of the Aerovox Model 85 capacitor selector.

TYPICAL CAPACITOR RATINGS FOR CAPACITOR START MOTORS

Motor Rating H.P.	Motor Speed RPM	Capacitors Ratings MFD
	3450	
1/8	1725	75-84
	1140	
	3450	
1/6	1725	89-96
	1140	
	3450	
1/4	1725	108-120
	1140	124-138
	3450	
1/3	1325	161-180
	1140	
	3450	
1/2	1725	216-240
	1140	
	3450	
3/4 & 1	1725	378-420
	1140	

29-8. Typical capacitor ratings for capacitor start motors.
(Aerovox Corp.)

Because of the wide diversity in capacitance and voltage ratings for motor starting and running oil capacitors, it is not practical to list the typical capacitors for different motor ratings.

POWER FACTOR CONTROL

In many cases it is possible to increase the power factor of a line by connecting power factor correction capacitors across the motors on that line. For this purpose oil-impregnated paper capacitors must be used. Fig. 29-9 gives the approximate total capacity required for various size motors operating at 220-240 volts 60 cycles 3-phase. These values can be used for single phase 220 volt 60 cycle motors. When used for 3-phase motors one third of the capacity required is connected across each pair of lines. For single phase operation, the total capacity given is connected across the line.

In addition to the increase in line capacity, the uses of the power factor capacitors will improve the voltage regulation of the line especially on long feeders.

The use of capacitors across lines supplying neon signs or fluorescent

CAPACITOR, POWER FACTOR, HORSE POWER TABLE

HP	Speed in RPM					
	3600	1800	1200	900	720	600
1/2			20	39		
3/4		15	24	36		
1	15	21	24	30		
1 1/2	15	21	36	54		
2	24	21	36	60		
3	24	24	51	75		
5	30	36	75	99	99	165
7 1/2	39	51	75	165	201	222
10	39	60	84	165	175	250

29-9. Approximate total capacity in mfds. required for power factor correction of standard 220-volt 3-phase induction motors. Approximately one-third of the values given should be used across each phase. (Aerovox Corp.)

tube lighting equipment will decrease the voltage fluctuations and flicker, due to sudden changes in load. In addition, use of capacitors will decrease to a certain extent the radio interference produced by these devices.

CAPACITY - CURRENT - POWER FACTOR CHART

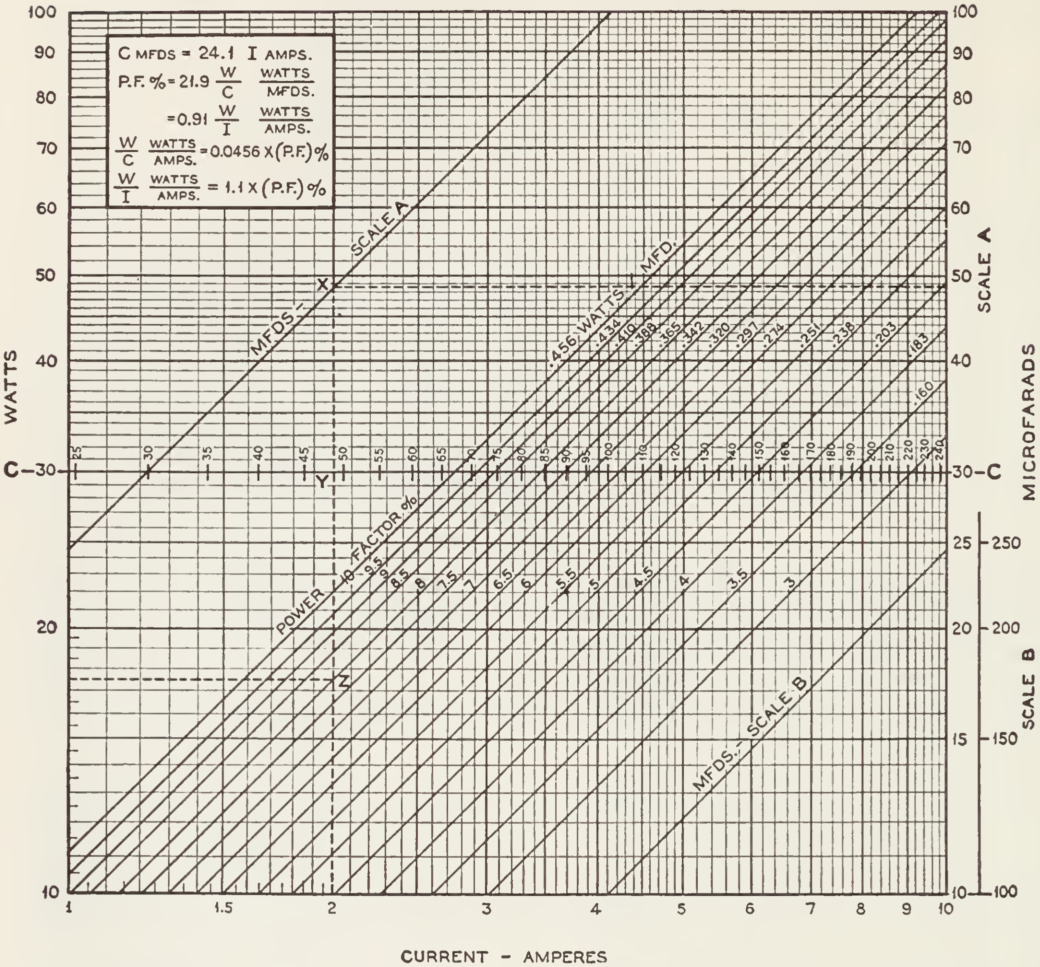
Instructions for the use of capacity - current - power factor chart for electrolytic motor starting capacitors. See Fig. 29-10.

1. To find the capacity of a capacitor from the current readings when the capacitor is connected across a 110-volt circuit draw a line vertically from the current scale to the line marked MFDS -scale A and read the capacity on the right-hand scale marked A. If the current drawn by the capacitor is greater than 4 amperes use scale marked MFDS -scale B and read the corresponding capacity on the right-hand scale marked B, in the lower right-hand corner of the chart. The capacity can also be found by reading the capacity on the scale marked C-C in the center of the chart.

   Example: To find the capacity of a capacitor which draws 2 amperes from a 110-volt line.

   From the point marked 2 amperes on the current scale, draw a perpendicular line to the scale marked MFDS-scale A. From the point of intersection, "X," draw a horizontal line to the right and read the capacity, 48 microfarads on scale A. The capacity may also read at the point "Y" where the vertical line crosses the scale marked C-C.

2. To find the power factor from the current and watt-meter readings, draw a horizontal line from the power scale on the left of the chart, and a vertical line from the current scale on the bottom of the chart. Read the power factor at the point of intersec-



29-10. Electrical characteristics of 110 volt electrolytic motor starting capacitors at 60 cycles. (Aerovox Corp.)

tion of the two lines. The capacity may be determined by extending the vertical line until it intersects the scale marked C-C or the scale marked MFDS-scale A or B.

Example: To find the power factor of a capacitor which draws 2 amperes and 16.5 watts from a 110-volt line.

Draw a horizontal line from the point marked 16.5 watts on the power scale at the left of the chart, and a vertical line from the point marked 2 amperes on the current scale, and

read the power factor at the point of intersection "Z." The power factor will be 8%.

3. To find the current that will flow when a given capacitor is connected across a 110-volt line, draw a horizontal line from the microfarad scale A or B, on the left of the chart to the corresponding MFDS line, and drop a perpendicular to the current scale at the bottom of the chart. The current can also be found by dropping a perpendicular line from the desired capacity value in microfarads on scale C-C to the current scale.

   Example: To find the current taken by a 48-microfarad capacitor when connected to a 110-volt line. Draw a horizontal line from 48 microfarads scale A to the MFDS-scale A, and drop a perpendicular line from the point of intersection "X" to the current scale on the bottom of the chart, and read 2 amperes.

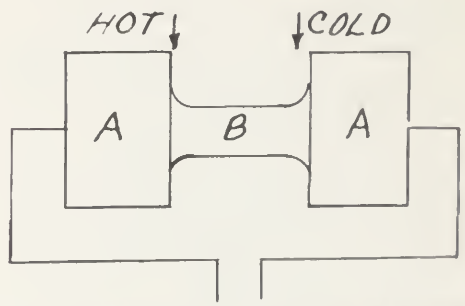
4. To find the power in watts for a capacitor of known capacity and power factor. Draw a vertical line from the value of capacity in microfarads on scale C-C to the power factor line given and then draw a horizontal line from the point of intersection to the power scale on the left of the chart.

   Example: To find the power of a 48-microfarad capacitor, 8% power factor when connected to a 110-volt line.

   From the point "Y", 48 microfarads, on scale C-C drop a perpendicular line until it intersects the 8% power factor line at the point "Z". From that point draw a horizontal line to the power scale on the left of the chart and read 16.5 watts.

29-3. PELETIER EFFECT

An interesting electrical-heat relation is the thermocouple. If two dissimilar metals are connected at one end and inserted in a fire, electric



29-11. A Peletier effect circuit. Direct current passing from one copper block A through the alloy B to the other copper block A produces a cold junction and a hot junction.

pressure and electron travel takes place if the other ends of the two metals are connected electrically.

The reverse of the electronic behavior is also true if electrons are passed between two metals. Their adjoining surfaces develop different temperatures. For example, if copper blocks are placed on each side of a steel alloy block, and a current is passed through the copper-steel-copper, one of the adjoining surfaces becomes cold, and one becomes hot, Fig. 29-11.

29-4. CLEANING METAL

During the course of use and during repair operations, metal parts may be-

come coated with lubricating oils, greases, oxides, dirt, metallic particles or abrasives.

There are a variety of methods successfully used to clean these metal parts. Lubricants or greases made from animal or vegetable oils or fats such as tallow, lard oil, palm oil, olive oil, can usually be removed by saponification (making a soap of the oil or fat). This is done by treating the parts in an alkaline solution where the oils react with the alkali to form water soluble soap compounds.

Unsaponifiable mineral oils such as kerosene, machine oil, cylinder oil and general lubricating oils are usually cleaned by an emulsification process using soaps, wetting agents and dispersing agents.

Dirt, abrasives, metal dust and inert materials are generally removed by one or both of these processes.

SOLVENT CLEANING is used for removing most of the oils from coated pieces, by immersing them in a solvent such as mineral spirits. The tanks should have safety lids and should be hooded and vented.

DEGREASING or vapor cleaning is also used to remove oils. By holding the parts in a container where solvent vapors can condense on the parts to be cleaned, the condensed solvent washes away the oily coating, leaving the work dry and nearly clean. Production degreasing machines use two or three compartments. The work is immersed in the first compartment containing a boiling solution of the solvent. It is then dipped into the second section, which contains clean cold solvent. Finally, it is hung in the third section where only clean vapors condense on and wash over the work. The degreasing unit is self purifying--oils and waste accumulating at bottom of third section. Job shop cleaning uses the third section only. The solvents used are generally chlorinated hydrocarbons such as carbon tetrachloride and trichlorethylene. Venting is of extreme importance for safety to the operator.

ALKALINE SCOURING. Alkaline cleaning baths are used primarily for the removal of oils, greases, solid particles of dirt, and metal particles by immersing pieces in hot alkaline solutions. The chemicals saponify or make soap of vegetable and animal oils and fats, emulsifying mineral oils and greases and suspending the solid material. The combination of heat, active chemicals and agitations are important factors. Soap is used either as a direct addition or is formed by the saponification of vegetable or animal fats present. Caustic soda, soda ash and causticized soda form the cheapest and most direct method of producing alkalinity in the bath. However, such materials, as a general rule, have less surface activity than more complex materials. Sodium metasilicate trisodium phosphate, and similar salts are often used to obtain alkalinity in a solution.

EMULSION SCRUBBING. A number of proprietary preparations are used for this purpose. They comprise an emulsification agent which acts to disperse organic solvents in water solutions. Emulsifiable cleaners are miscible with oils and can be washed off with water, although a film of oil may remain on the work and necessitate a subsequent alkali cleaning treatment. Dragout costs are high.

ELECTROLYTIC CLEANING. Alkaline materials are used in electrolytic cleaning. The bath is maintained at as near boiling as permissible without excessive tarnishing. The gas evolved tends to lift off the soil, presenting a clean surface for subsequent operations. The work to be cleaned is usually made the cathode. There are many

formulas available for this work but the one used depends upon the nature of the material to be used and the degree of tarnish permissible. In many cases, particularly with carbon steel or cast iron, unusual results can be obtained by switching the polarity several times during cleaning.

TARNISH REMOVAL. Brass and copper articles often become discolored or tarnished on standing or during the course of alkaline cleaning. This tarnish can be removed when work is free from oil or grease by immersion in a water solution containing 4 to 8 ounces of sodium cyanide per gallon. After discoloration has been removed--usually a matter of seconds--pieces should be thoroughly rinsed. Sodium cyanide is very poisonous and extreme care must be observed during handling. When work is cleaned in alkali, the alkali should be completely removed because if alkali and cyanide are mixed and allowed to stand, ammonia may be developed. Care must be taken not to allow any cyanide to come in contact with acids because of liberation of lethal hydro-cyanic acid gas. Even though the above precautions must be carefully observed, many gallons of cyanide solution are used daily, particularly in plating cycles.

PICKLING. The pickling operation is used to remove oxides or films which usually develop on the surface of the metals from annealing. Inorganic acids are generally used for this purpose, sulphuric acid and hydrochloric acid being the more common ones. Either sodium bichromate or ferric sulphate are used in combination with an acid to remove red stains on brass or to produce a special surface effect. After pickling it is important that metals be rinsed well and, if permissible, immersed in a neutralizer to remove the last traces of acid.

SULPHURIC ACID PICKLE

Sulphuric Acid	1/4 to 1 gallon
Water.	4 gallons
Temperature	100 to 160 F.

Used frequently after an annealing operation where scale and tarnish has been developed. Usually the heavier the scale, the more concentrated and hotter is the pickle which is used.

SODIUM BICHROMATE PICKLE

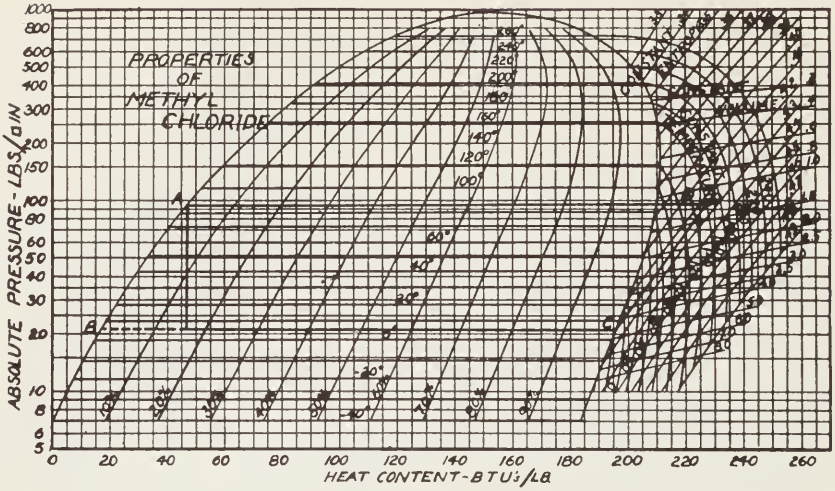
Sulphuric Acid	1/4 gallon
Water.	4- 1/2 gallons
Sodium Bichromate .	2 to 5 oz. per gal.
Temperature	80 to 120 F.

The lowest concentrate of chemicals that will do the required brightening is recommended. If pieces remain too long in this solution or solution is too concentrated, some pitting or etching of the surface may result. When properly employed it will give a clear yellow surface finish which is not glossy. Sodium Bichromate pickle is used for removing red stains which remain after sulphuric acid pickling.

BRIGHT DIP

Sulphuric Acid	2 gallons
Nitric Acid	1 gallon
Water.	1 quart
Hydrochloric Acid. .	1 oz. to every 5 gals.
Operate	Cold, room temperature

To obtain a gloss, a bright dip solution is required. There are many possible combinations which will give the desired results. Increasing the nitric acid makes the solution more active. Increasing the sulphuric acid slows down the action of the solution. Add salt carefully and in small quantities if work is sooty.



29-12. Pressure-heat graph for methyl chloride.
(American Society Refrigerating Engineers)

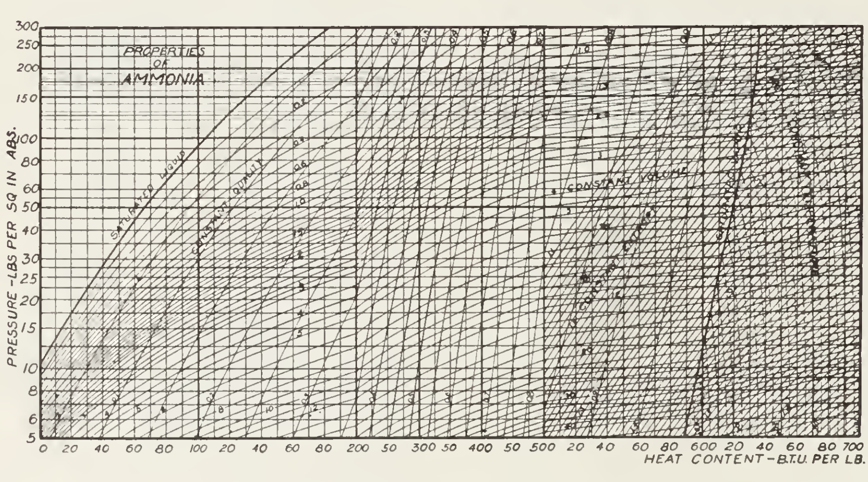
SCALE DIP. Sometimes a preliminary preparation of the surface is necessary before immersing the pieces in the bright dip, especially when a very bright, smooth surface is desired.

(a) Where very heavy cutting of the surface is desired, use concentrated nitric acid as received from the carboy.

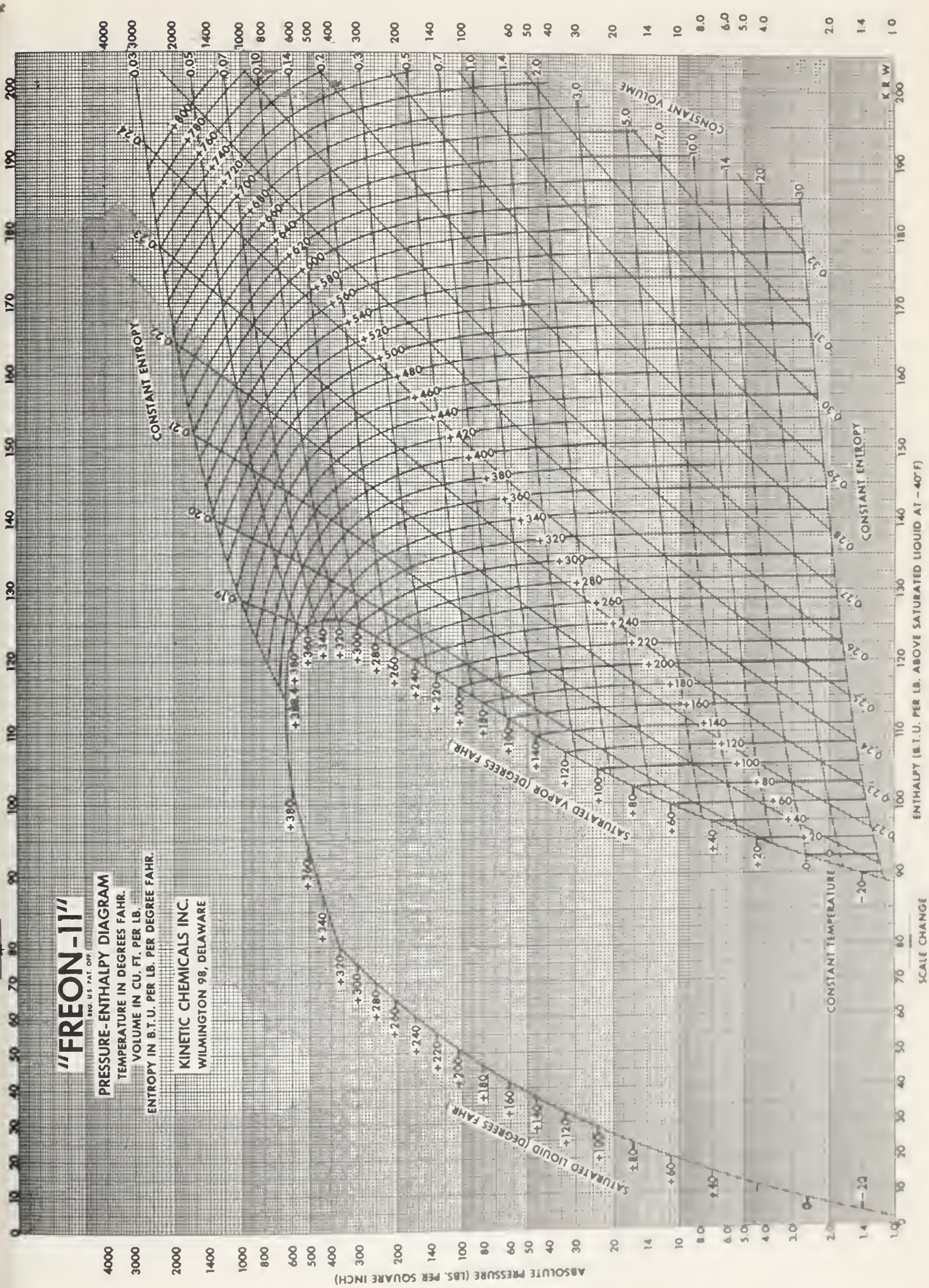
(b) For milder treatment, use the formula:

Nitric acid . . . . 1 gallon
Sulphuric acid . . . . . . 1 to 2 gallons
Water. . . . . 1 to 5 gallons

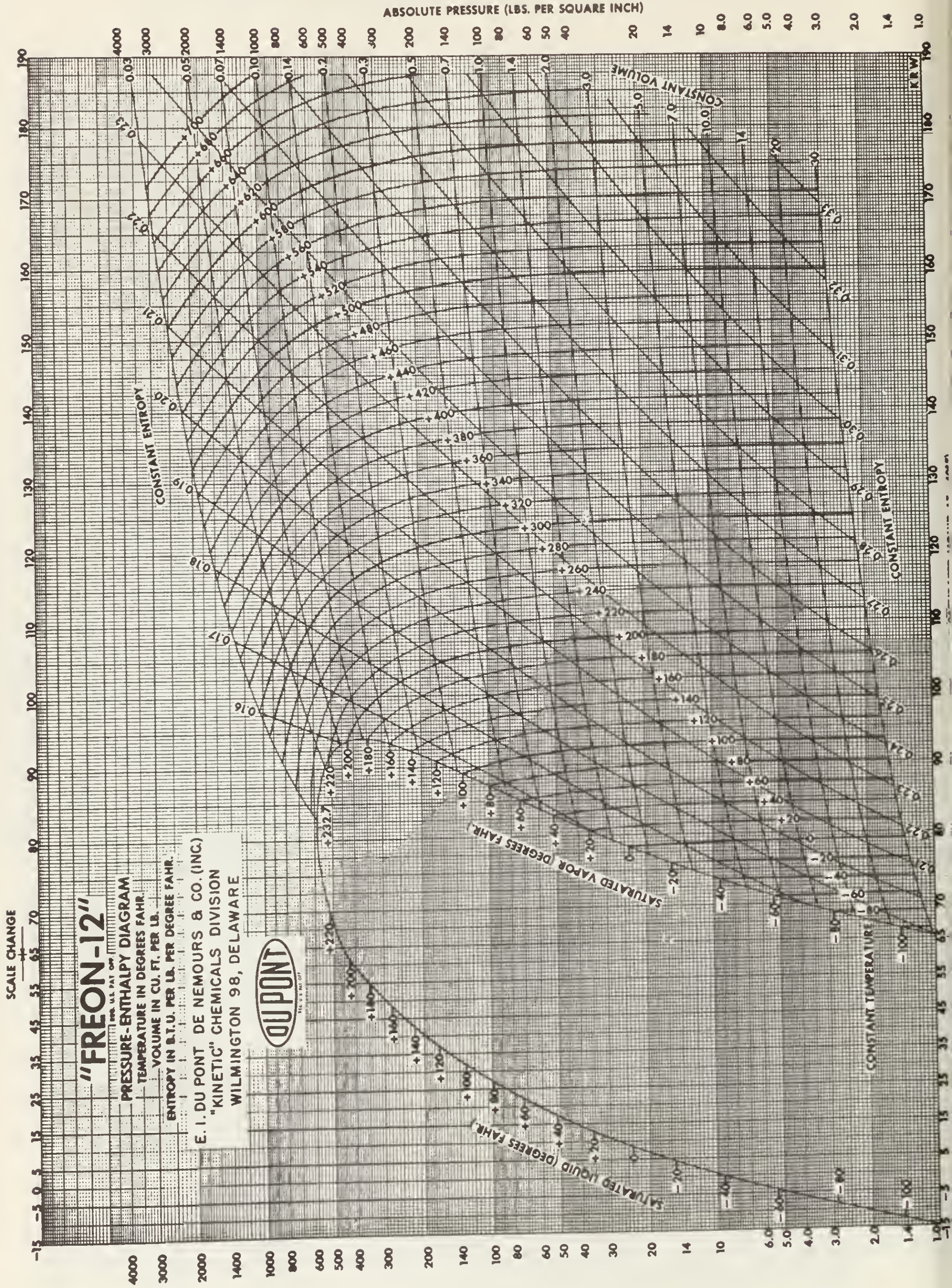
These solutions are quite active and must be used with care to prevent too deeply attacking the brass. After the bright dipping, either preceded by scale or bichromate dipping, the work should be thoroughly rinsed in water, immersed in 2 to 4 ounce solution of sodium cyanide followed by thorough rinsing. Then immerse in 1 ounce solution of neutral soap, and thoroughly



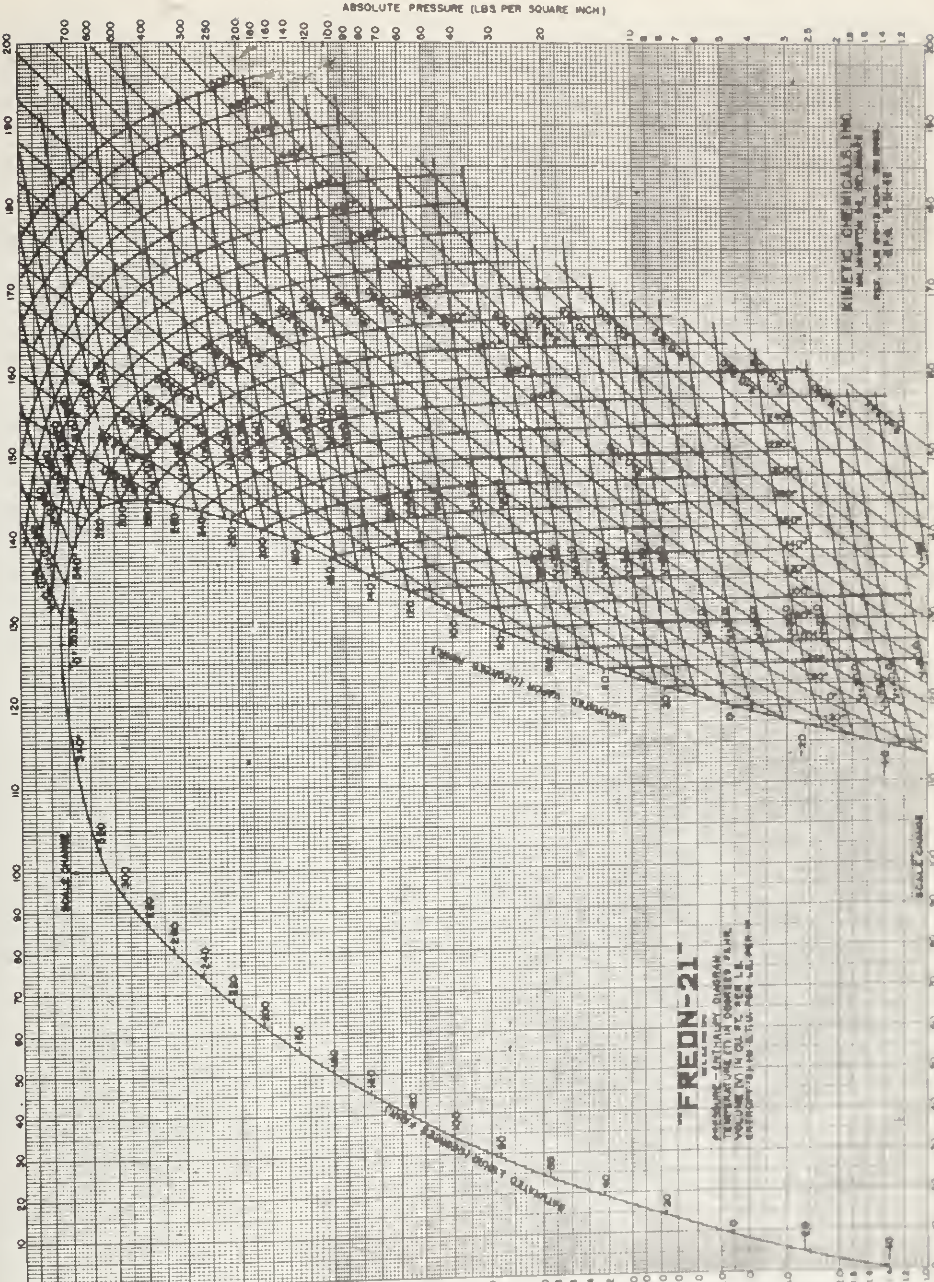
29-13. Pressure-heat graph for ammonia (NH_3).
(American Society Refrigerating Engineers)



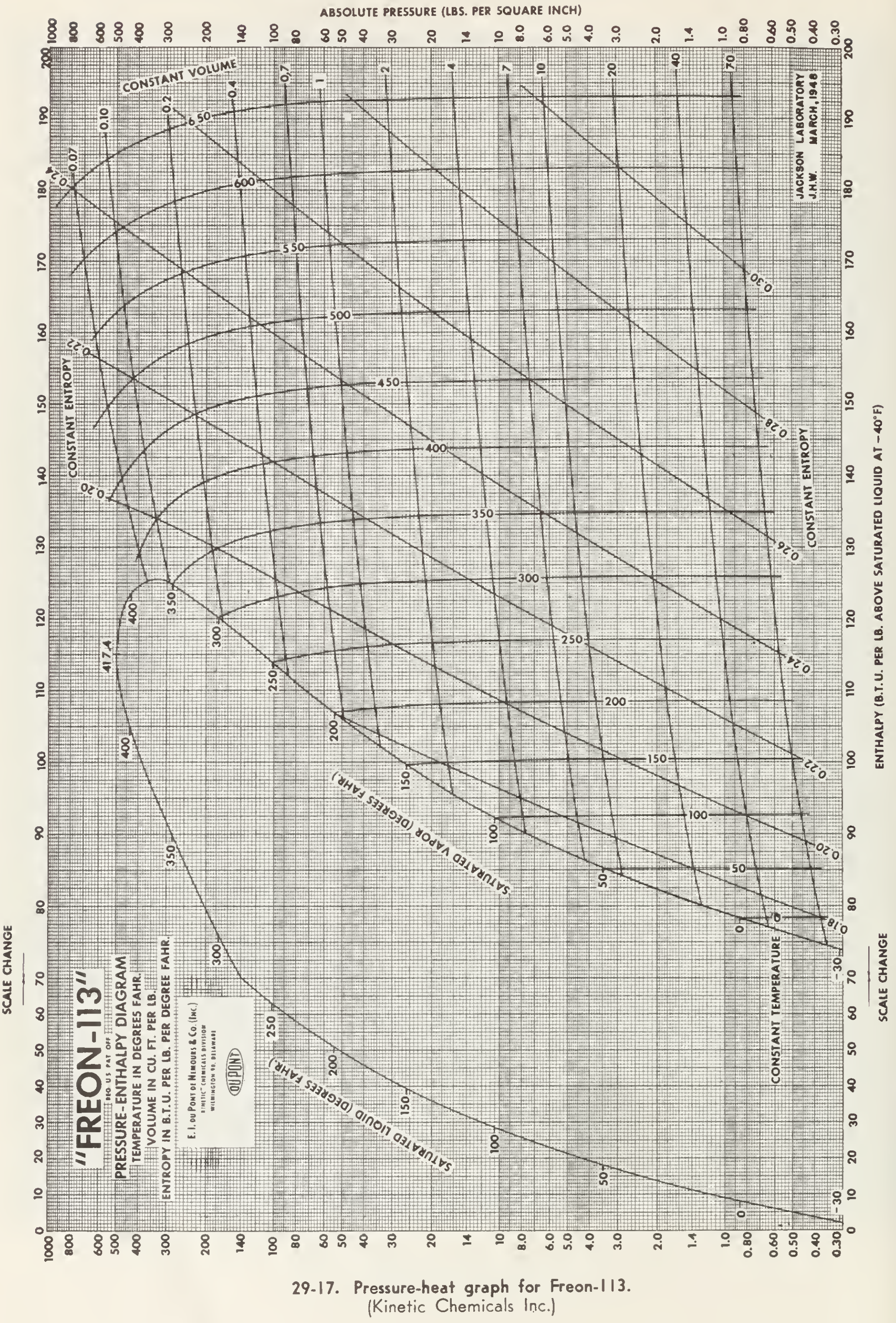
29-14. Pressure-heat graph for Freon-11.
(Kinetic Chemicals Inc.)



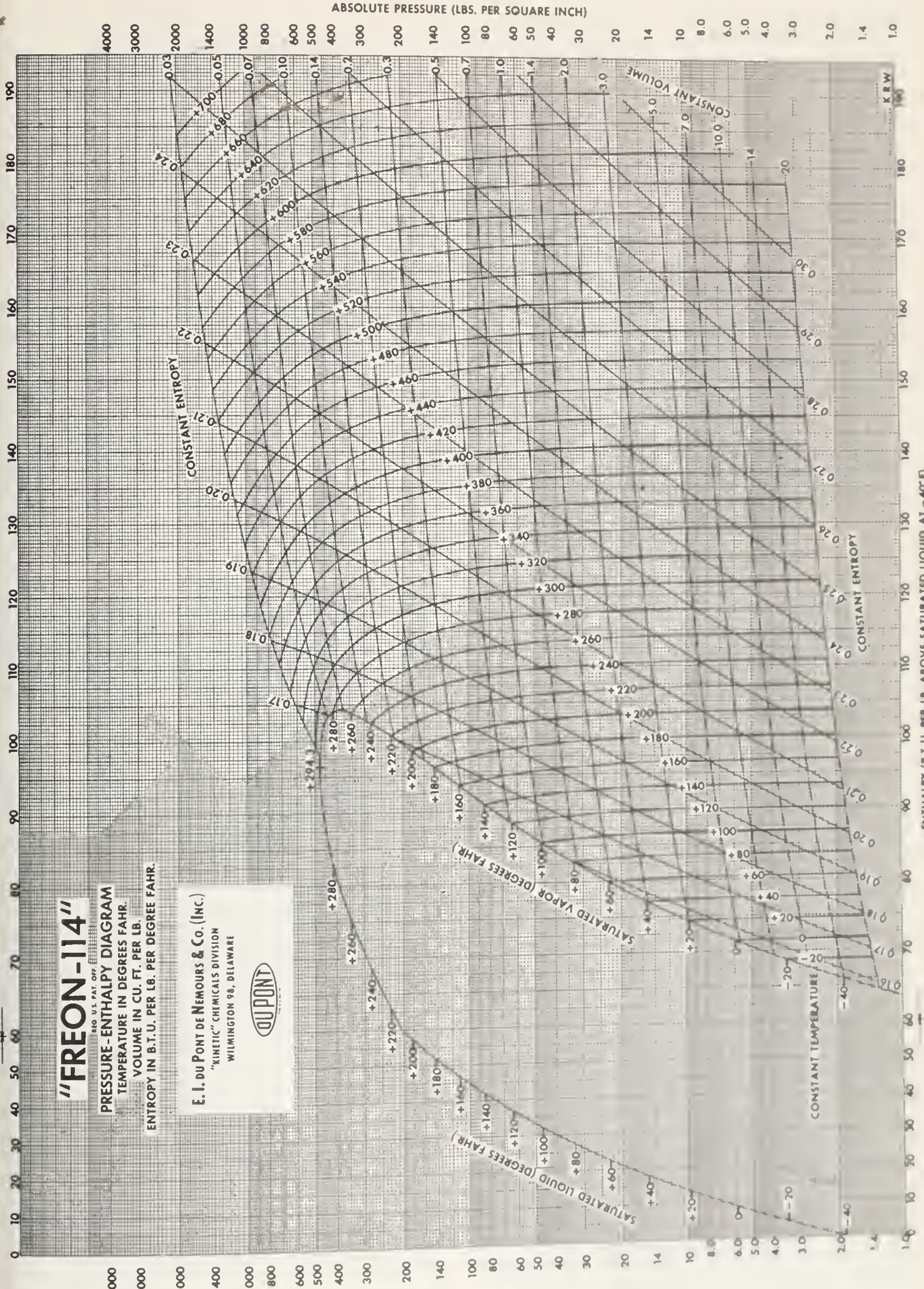
29-15. Pressure-heat graph for Freon-12.
(Kinetic Chemicals Inc.)



29-16. Pressure-heat graph for Freon-21.
(Kinetic Chemicals Inc.)



29-17. Pressure-heat graph for Freon-113.
(Kinetic Chemicals Inc.)



29-18. Pressure-heat graph for Freon-114.
(Kinetic Chemicals Inc.)

rinse. Omit the soap solution if pieces are to be soldered. Ferric sulphate can be used in place of sodium bichromate, and for certain purposes it is preferred, particularly where attack of base metal is to be kept to the minimum.

29-5. REFRIGERANT CHARACTERISTICS

Several pressure-heat enthalpy diagrams are given in this section. Most of the physical properties of refrigerants may be ascertained from these graphs. See Figures 29-12 through 29-18.

29-6. FOOD PRESERVATION BY RADIATION TREATMENT

Experiments have been conducted using atomic energy radiations to preserve food. Fresh foods have been put in sealed containers. These containers were exposed to a form of atomic energy radiation. It was found, upon inspection, that the food remains indefinitely in its fresh state with no change in appearance, flavor or food value, as a result of being treated in this manner.

29-7. SAFETY CODE FOR MECHANICAL REFRIGERATION

Section 1. SCOPE AND PURPOSE

1.1 Scope. The application of this Code is intended to insure the safe design, construction, installation, operation, and inspection of every *refrigerating system* employing a fluid which is vaporized and is normally liquefied in its refrigerating cycle, when employed under the occupancy classifications listed in Section 3. The provisions of this Code are not intended to apply to the use of water or air as a *refrigerant* nor to *refrigerating systems* installed on railroad cars, motor vehicles, motor drawn vehicles or on shipboard. (For shipboard installations see ASA B59.1-1950).

1.2 Purpose. This Code is intended to provide reasonable safeguards to life, limb, health, and property; to correct certain practices which are inconsistent with safety; and to prescribe standards of safety which will properly influence future progress and developments in *refrigerating systems.* Equipment listed by an approved, nationally recognized testing laboratory, as defined in 2.3.1, is deemed to meet the design, manufacture, and factory test requirements of this Code or equivalent, for the *refrigerant* or *refrigerants* for which such equipment is designed.

1.3 Application. This Code shall apply to *refrigerating systems* installed subsequent to its adoption and to parts replaced or added to systems installed prior or subsequent to its adoption. In cases of practical difficulty or unnecessary hardship, the authority having jurisdiction may grant exceptions from the literal requirements of this Code or permit the use of other devices or methods, but only when it is clearly evident that equivalent protection is thereby secured.

NOTE: To secure the uniform application of this Code, authorities having jurisdiction are urged, before renderin decisions on disputed points, to consult the committee whic formulated it—the Committee on Safety Code for Mechan cal Refrigeration, B9, in care of the American Standarc Association, Incorporated, 70 East 45th Street, New Yo 17, N. Y., or the American Society of Refrigerating Eng neers, 40 West 40th Street, New York 18, N. Y.

Section 2. DEFINITIONS

2.1 *Absorber (Adsorber)* is that part of the *lo side* of an *absorption system* used for absorbin (adsorbing) vapor *refrigerant.*

2.2 *Absorption System*—see 2.48.1.

2.3 *Approved* means acceptable to the authoriti having jurisdiction.

2.3.1 *An Approved Nationally Recognized Tes ing Laboratory* is one acceptable to the authoriti having jurisdiction, that provides uniform testi and examination procedures under establish standards, is properly organized, equipped an qualified for testing, and has a follow-up inspe tion service of the current production of the liste products.

2.4 *Brazed Joint,* for the purpose of this code, is gas-tight joint obtained by the joining of met parts with alloys which melt at temperatur higher than 1000 F but less than the melting ten peratures of the joined parts.

2.5 *Brine* is any liquid, used for the transmissi of heat without a change in its state, having flash point or a flash point above 150 F determin by American Society for Testing Materials meth D93-52. (See Appendix 1.)

2.6 *Compressor* is a specific machine, with or wit out accessories, for compressing a given *refrigera* vapor.

Compressor Unit is a *condensing unit* less the ...enser and *liquid receiver*.

... *Condenser* is a vessel or arrangement of pipe ...ubing in which vaporized *refrigerant* is lique... by the removal of heat.

... *Condensing Unit* is a specific refrigerating ...hine combination for a given *refrigerant*, con...ing of one or more power-driven *compressors*, ...densers, liquid receivers* (when required), and ... regularly furnished accessories.

... *Container* is a cylinder for the transportation ...efrigerant*. (See Appendix 2.)

... *Department Store* is the entire space occupied ...one *tenant* or more than one *tenant* in an indi...ual store where more than 100 persons com...nly assemble on other than the street-level floor ... the purpose of buying personal wearables and ...ler merchandise.

... *Design Working Pressure* is the maximum al...able working pressure for which a specific part ... system is designed.

... *Direct System*—see 4.2.

... *Double Indirect Vented Open-Spray System*—... 4.3.4.

... *Double (or Secondary) Refrigerant System*—... 4.4.

...3 *Duct* is a tube or conduit used for conveying ...encasing purposes as specifically defined below:

...) *Air duct* is a tube or conduit used for conveying air. (The air passages of *self-contained systems* are not to be construed as *air ducts*.)

...) *Pipe duct* is a tube or conduit used for encasing pipe.

...) *Wire duct* is a tube or conduit used for encasing either moving or stationary wire, rope, etc.

...19 *Entrance* is a confined passageway immediate...adjacent to the door through which people enter ...building.

...20 *Evaporator* is that part of the system in which ...uid *refrigerant* is vaporized to produce refriger...on.

...21 *Exit* is a confined passageway immediately ...acent to the door through which people leave a ...lding.

...22 *Expansion Coil* is an *evaporator* constructed ... pipe or tubing.

...3 *Fusible Plug* is a device having a predeter...ned-temperature fusible member for the relief ... pressure.

...4 *Generator* is any device equipped with a heat...g element used in the *refrigerating system* to ...crease the pressure of *refrigerant* in its gas or ...por state for the purpose of liquefying the *refrig...ant*.

...5 *Hallway* is a corridor for the passage of peo...e.

...6 *High Side* means the parts of a *refrigerating ...stem* under *condenser* pressure.

...7 *Humanly Occupied Space* is a space normally ...equented or occupied by people but excluding *machinery rooms* and walk-in coolers used primarily for refrigerated storage.

2.28 *Indirect Closed-Surface System*—see 4.3.2.

2.29 *Indirect Open-Spray System*—see 4.3.1.

2.30 *Indirect System*—see 4.3.

2.31 *Indirect Vented Closed-Surface System*—see 4.3.3.

2.32 *Liquid Receiver* is a vessel permanently connected to a system by inlet and outlet pipes for storage of a liquid *refrigerant*.

2.33 *Lobby* is a waiting room, or large *hallway* serving as a waiting room.

2.34 *Low Side* means the parts of a *refrigerating system* under *evaporator* pressure.

2.35 *Machinery* is the refrigerating equipment forming a part of the *refrigerating system* including any or all of the following: *compressor, condenser, generator, absorber (adsorber), liquid receiver*, connecting pipe, or *evaporator*.

2.36 *Machinery Room* is a room in which a *refrigerating system* is permanently installed and operated but not including *evaporators* located in a cold storage room, refrigerator box, air cooled space, or other enclosed space. Closets solely contained within, and opening only into, a room *shall* not be considered *machinery rooms* but *shall* be considered a part of the *machinery room* in which they are contained or open into. It is not the intent of this definition to cause the space in which a *self-contained system* is located to be classified as a *machinery room*. (See 8.11.)

2.37 *Machinery Room, Class T* is a room having *machinery* but no flame-producing apparatus permanently installed and operated and also conforming to the following:

a) Any doors, communicating with the building, *shall* be *approved* self-closing, tight-fitting fire doors.

b) Walls, floor, and ceiling *shall* be tight and of not less than one-hour fire-resistive construction.

c) It *shall* have an *exit* door which opens directly to the outer air or through a vestibule-type *exit* equipped with self-closing, tight-fitting doors.

d) Exterior openings, if present, *shall not* be under any fire escape or any open stairway.

e) All pipes piercing the interior walls, ceiling, or floor of such room *shall* be tightly sealed to the walls, ceiling, or floor through which they pass.

f) Emergency remote controls to stop the action of the *refrigerant compressor shall* be provided and located immediately outside the *machinery room*.

g) Mechanical means *shall* be provided for ventilation. (See 8.11.3.)

h) Emergency remote controls for the mechanical means of ventilation *shall* be provided and located outside the *machinery room*.

2.38 *Manufacturer* is, for the purpose of this code, the company or organization which evidences its

responsibility by affixing its name or nationally registered trade-mark or trade name to the refrigeration equipment concerned.

2.39 *Mechanical Joint*, for the purpose of this code, is a gas-tight joint, obtained by the joining of metal parts through a positive-holding mechanical construction.

2.40 *Nonpositive Displacement Compressor* is a *compressor* in which increase in vapor pressure is attained without changing the internal volume of the compression chamber.

2.41 *Piping* means the pipe or tube mains for interconnecting the various parts of a *refrigerating system.*

2.42 *Positive Displacement Compressor* is a *compressor* in which increase in vapor pressure is attained by changing the internal volume of the compression chamber.

2.43 *Pressure-Imposing Element* is any device or portion of the equipment used for the purpose of increasing the *refrigerant* vapor pressure.

2.44 *Pressure-Limiting Device* is a pressure-responsive mechanism designed to automatically stop the operation of the *pressure-imposing element* at a predetermined pressure.

2.45 *Pressure-Relief Device* is a pressure-actuated valve or *rupture member* designed to automatically relieve excessive pressure.

2.46 *Pressure-Relief Valve* is a pressure-actuated valve held closed by a spring or other means and designed to automatically relieve pressure in excess of its setting.

2.47 *Pressure Vessel* is any refrigerant-containing receptacle of a *refrigerating system*, other than *evaporators*, each separate section of which does not exceed ½ cubic foot of refrigerant-containing volume, *expansion coils, compressors,* controls, headers, pipe, and pipe fittings.

2.48 *Receiver*—see 2.32.

2.49 *Reciprocating Compressor* is a *positive displacement compressor* with a piston or pistons moving in a straight line but alternately in opposite directions.

2.50 *Refrigerant* is a substance used to produce refrigeration by its expansion or vaporization.

2.51 *Refrigerating System* is a combination of interconnected refrigerant-containing parts constituting one closed *refrigerant* circuit in which a *refrigerant* is circulated for the purpose of extracting heat. (See Section 4 for classification of *refrigerating systems* by type.)

2.51.1 *Absorption System* is a *refrigerating system* in which the gas evolved in the *evaporator* is taken up by an *absorber* or *adsorber.*

2.51.2 *Centrifugal System* is a specific combination of *machinery* for a given *refrigerant*, consisting of a power-driven *centrifugal compressor*, a *condenser*, a water or other liquid cooler, and the regularly furnished accessories. The component parts, after assembly and testing at the factory, are usually disassembled for shipment.

2.51.3 *Sealed Absorption System* is a *unit system* for Group 2 *refrigerants* only in which all refrig erant-containing parts are made permanently tigh by welding or brazing against *refrigerant* los (This is a restrictive definition for the purposes c this code as used in 6.1.2 and 6.3.1.) (See 2.51.1.

2.51.4 *Self-Contained System* is a complete fa tory-made and factory tested system in a suitabl frame or enclosure which is fabricated and shippe in one or more sections and in which no refrige ant-containing parts are connected in the field othe than by companion or block valves.

2.51.5 *Unit System* is a *self-contained syste* which has been assembled and tested prior to it installation and which is installed without co necting any refrigerant-containing parts. A *un system* may include factory-assembled companio or block valves.

2.52 *Rupture Member* is a device that will aut matically rupture at a predetermined pressure.

2.53 *Shall.* Where *"shall"* or *"shall not"* is used fo a provision specified, that provision is intended t be mandatory.

2.54 *Should.* *"Should"* or *"it is recommended"* used to indicate provisions which are not mand tory but which are pointed out here as recon mended good practice.

2.55 *Sealed Absorption System*—see 2.51.3.

2.56 *Self-Contained System*—see 2.51.4.

2.57 *Soldered Joint*, for the purpose of this cod is a gas-tight joint obtained by the joining of met parts with metallic mixtures or alloys which me at temperatures below 1000 F and above 400 F.

2.58 *Stop Valve* is a shut-off for controlling th flow of *refrigerant.*

2.59 *Tenant*, as herein used, *shall* be contrued as person, firm, or corporation possessed with th legal right to occupy premises.

2.60 *Unit System*—see 2.51.5.

2.61 *Welded Joint*, for the purpose of this code, a gas-tight joint, obtained by the joining of met parts in the plastic or molten state.

Section 3. BUILDING OCCUPANCY CLASSIFICATION

3.1 Locations in which *refrigerating systems* m be placed are grouped by occupancy as follows:

3.2 Institutional Occupancy *shall* apply to that po tion of a building in which persons are confined receive medical, charitable, educational, or oth care or treatment, or in which persons are held detained by reason of public or civic duty, inclu ing among others, hospitals, asylums, sanitarium police stations, jails, court houses with cells, a similar occupancies.

3.3 Public Assembly Occupancy *shall* apply to th portion of the premises in which persons congr gate for civic, political, educational, religious, s cial, or recreational purposes; including amo others, armories, assembly rooms, auditoriums, b rooms, bath houses, bus terminals, broadcasti studios, churches, colleges, court houses witho cells, dance halls, *department stores,* exhibiti

alls, fraternity halls, libraries, lodge rooms, mor-
tuary chapels, museums, passenger depots, schools, skating rinks, subway stations, theaters, and similar occupancies.

4 **Residential Occupancy** *shall* apply to that portion f a building in which sleeping accommodations are rovided for more than two families, including mong others, club houses, convents, dormitories, otels, lodging houses, multiple story apartments, udios, tenements, and similar occupancies.

5 **Commercial Occupancy** *shall* apply to that poron of a building used for the transaction of busiess; for the rendering of professional services; or the supplying of food, drink, or other bodily eeds and comforts; for manufacturing purposes r for the performance of work or labor (except s included under 3.6 Industrial Occupancy) inuding among others, bake shops, fur storage, labratories, loft buildings, markets, office buildings, rofessional buildings, restaurants, stores other han *department stores,* and similar occupancies.

.6 **Industrial Occupancy** *shall* apply to an entire uilding when used by a single *tenant* for manuacturing, processing, or storage of materials or roducts, including among others, chemical, food, andy, and ice cream factories, ice making plants, neat packing plants, refineries, perishable food arehouses, and similar occupancies.

.7 **Mixed Occupancy** *shall* apply to a building occuied or used for different purposes in different arts. When the occupancies are cut off from the est of the building by tight partitions, floors, and eilings and protected by self-closing doors, the reuirements for each type of occupancy *shall* apply or its portion of the building. For example, the old storage spaces in retail frozen food lockers, otels, and *department stores* might be classified nder Industrial Occupancy, whereas other portions f the buildings would be classified under ther occupancies. When the occupancies are ot so separated, the occupancy carrying the more tringent requirements *shall* govern.

Section 4. REFRIGERATING SYSTEM CLASSIFICATION BY TYPE

.1 **Refrigerating Systems** (see 2.51) *shall* be divided nto classes, descriptive of the method employed for xtracting heat as follows in 4.2 to 4.4, inclusive. The *direct* and various *indirect systems* referred to re illustrated in Figure 1.

.2 **Direct System** is one in which the *evaporator* is n direct contact with the material or space refrigrated or is located in air-circulating passages comnunicating with such spaces.

.3 **Indirect System** is one in which a liquid, such as *rine* or water, cooled by the *refrigerant,* is circuated to the material or space refrigerated or is sed to cool air so circulated. *Indirect systems* which are distinguished by the type or method of pplication are as given in the following pararaphs:

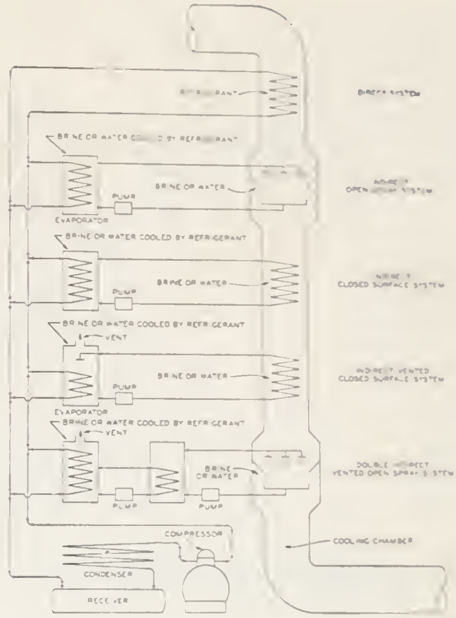


FIG. 1

4.3.1 *Indirect Open-Spray System* is one in which a liquid, such as *brine* or water, cooled by an *evaporator* located in an enclosure external to a cooling chamber, is circulated to such cooling chamber and is sprayed therein.

4.3.2 *Indirect Closed-Surface System* is one in which a liquid, such as *brine* or water, cooled by an *evaporator* located in an enclosure external to a cooling chamber, is circulated to and through such a cooling chamber in pipes or other closed circuits.

4.3.3 *Indirect Vented Closed-Surface System* is one in which a liquid, such as *brine* or water, cooled by an *evaporator* located in a vented enclosure external to a cooling chamber, is circulated to and through such cooling chamber in pipes or other closed circuits.

4.3.4 *Double Indirect Vented Open-Spray System* is one in which a liquid, such as *brine* or water, cooled by an *evaporator* located in a vented enclosure, is circulated through a closed circuit to a second enclosure where it cools another supply of a liquid, such as *brine* or water, and this liquid in turn is circulated to a cooling chamber and is sprayed therein.

4.4 **Double (or Secondary) Refrigerant System** is one in which an evaporative *refrigerant* is used in a secondary circuit. For the purpose of this code, each system enclosing a separate body of an evaporative *refrigerant shall* be considered as a separate *direct system.*

Section 5. REFRIGERANT CLASSIFICATION

5.1 **General.** *Refrigerants* are, for the purposes of this code, divided into groups as follows:

5.1.1 *Group 1*

Carbon dioxide	CO_2
Dichlorodifluoromethane (Freon-12)	CCl_2F_2
Dichloromethane (Carrene No. 1) (Methylene chloride)	CH_2Cl_2
Dichloromonofluoromethane (Freon-21)	$CHCl_2F$
Dichlorotetrafluoroethane (Freon-114)	$C_2Cl_2F_4$
Monochlorodifluoromethane (Freon-22)	$CHClF_2$
Trichloromonofluoromethane (Freon-11) (Carrene No. 2)	CCl_3F
Trichlorotrifluoroethane (Freon-113)	$C_2Cl_3F_3$

5.1.2 *Group 2*

Ammonia	NH_3
Dichloroethylene	$C_2H_2Cl_2$
Ethyl chloride	C_2H_5Cl
Methyl chloride	CH_3Cl
Methyl formate	$HCOOCH_3$
Sulphur dioxide	SO_2

5.1.3 *Group 3*

Butane	C_4H_{10}
Ethane	C_2H_6
Ethylene	C_2H_4
Isobutane	$(CH_3)_3CH$
Propane	C_3H_8

Section 6. REQUIREMENTS FOR INSTITUTIONAL, PUBLIC ASSEMBLY, RESIDENTIAL, AND COMMERCIAL OCCUPANCIES

6.1 General

6.1.1 *Public Stairway, Stair Landing, Entrance, or Exit.* No *refrigerating system shall* be installed in or on a public stairway, stair landing, *entrance,* or *exit.*

6.1.2 *Public Hallway or Lobby.* No *refrigerating system shall* interfere with free passage. No Group 2 *refrigerant shall* be permitted in public *hallways* or *lobbies* of Institutional or Public Assembly Occupancies. *Refrigerating systems* installed in a public *hallway* or *lobby shall* be limited to:

a) *Unit Systems* containing not more than the quantities of a Group 1 *refrigerant* specified in Table 1, or

b) *Sealed Absorption Systems* containing not more than 3 pounds of Group 2 *refrigerant* when in Residential and Commercial Occupancies.

6.1.3 *Refrigerant Piping Through Floors. Refrigerant piping shall not* be carried through floors except as follows:

a) It may be carried from the basement to the first floor or from the top floor to a *machinery* penthouse or to the roof.

b) For the purpose of connecting to a *condenser* on the roof, it may be carried through an *approved,* rigid and tight continuous fire-resisting *pipe duct* or shaft having no openings on intermediate floors, or it may be carried on the outer wall of the building provided it is not located in an air shaft, closed court, or in other similar open spaces enclosed within the outer walls of the building.

c) In systems containing Group 1 *refrigerants,* the *refrigerant piping* may also be carried through floors, intermediate between the first floor and the top floor, provided it is enclosed in an *approved,* rigid, and tight continuous fire-resisting *pipe duct* or shaft where it passes through any intermediate space. Where the *refrigerating system* serves an air conditioning system, the *piping* need not be enclosed where it passes through air conditioned spaces served by that system. The *pipe duct* or shaft *shall* be vented to the outside or to a space served by the air conditioning system.

TABLE 1. Maximum Permissible Quantities of Group 1 Refrigerants for Direct Systems

Refrigerant name	*Chemical formula*	*Maximum quantity in lb per 1000 cu ft of humanly occupied space**
Carbon dioxide	CO_2	11
Dichlorodifluoromethane (Freon-12)	CCl_2F_2	31
Dichloromethane (Methylene chloride), (Carrene No. 1)	CH_2Cl_2	6
Dichloromonofluoromethane (Freon-21)	$CHCl_2F$	13
Dichlorotetrafluoroethane (Freon-114)	$C_2Cl_2F_4$	44
Monochlorodifluoromethane (Freon-22)	$CHClF_2$	22
Trichloromonofluoromethane (Freon-11)	CCl_3F	35
Trichlorotrifluoroethane (Freon-113)	$C_2Cl_3F_3$	24

*NOTES:

a) When the refrigerant-containing parts of a system are located in one or more enclosed spaces, the cubical content of the smallest enclosed *humanly occupied space* other than the *machinery room, shall* be used to determine the permissible quantity of *refrigerant* in the system.

b) When the *evaporator* is located in an *air duct* system, cubical content of the smallest humanly occupied enclosed space served by the *air duct* system *shall* be used to determine the permissible quantity of *refrigerant* in the system; however, if the air flow to any enclosed space served by the *air duct* system cannot be shut off or reduced below one-quarter of its maximum, the cubical contents of the entire space served by the *air duct* system may be used to determine the permissible quantity of *refrigerant* in the system.

c) Volatile charge in a control *shall not* be considered as *refrigerant.*

6.2 Group 1 Refrigerants

6.2.1 *Direct Systems.* The maximum permissible quantity of a Group 1 *refrigerant* in a *direct system* is specified in Table 1 except Institutional Occupancies where further limited by 6.2.1.1.

6.2.1.1 *Direct Systems* in Institutional Occupancies *shall* be limited to *unit systems* containing not more than 20 pounds of Group 1 *refrigerants,* except in kitchens, laboratories, and mortuaries. (See 6.2.4.)

6.2.1.2 In Institutional and Public Assembly Occupancies, direct *expansion coils* or *evaporators* used for air conditioning and located downstream from, and in proximity to, a heating coil, or located upstream within 18 inches of a heating coil, *shall* be fitted with a relief device discharging to the outside of the building in an *approved* manner; except that such a relief device *shall not* be required on *unit* or *self-contained systems* if the

internal volume of the *low side* of the system which may be shut off by valves, divided by the total weight of *refrigerant* in the system less the weight of *refrigerant* vapor contained in the other parts of the system at 110 F, exceeds the specific volume of the *refrigerant* at critical conditions of temperature and pressure.

(NOTE: The above exemption is also stated in formula form below.)

$$\frac{V_1}{W_1 - W_2} \text{ shall be more than } V_{sp}$$

where V_1 = *low side* volume, cu ft

V_{sp} = specific volume at critical conditions of temperature and pressure, cu ft per lb

W_1 = total weight of *refrigerant* in system, lb

W_2 = weight of *refrigerant* vapor (lb) at 110 F in V_2, or

$$= \frac{V_2}{\text{specific volume of } refrigerant\text{, in cu ft per lb, at 110 F,}}$$

where V_2 = total volume of system less V_1, cu ft

6.2.2 *Indirect Systems.* A system containing more than the quantity of a Group 1 *refrigerant* allowed in Table 1 *shall* be of the *indirect* type with all refrigerant-containing parts, excepting parts mounted outside the building, installed in a *machinery room* used for no other purpose than for mechanical equipment.

6.2.3 *Open Flames in Machinery Rooms.* No open flame or apparatus to produce an open flame *shall* be installed in a *machinery room* where any *refrigerant* other than carbon dioxide is used unless the flame is enclosed and vented to the open air. The use of matches, cigarette lighters, halide leak detectors, and similar devices *shall not* be considered a violation of this paragraph or of 6.2.4.

6.2.4 *Open Flames in Institutional and Public Assembly Occupancies.* In Institutional and Public Assembly Occupancies, when more than 1 pound of a Group 1 *refrigerant*, other than carbon dioxide, is used in a system any portion of which is in a room where there is an apparatus for producing an open flame, then such *refrigerant shall* be classed in Group 2 unless the flame-producing apparatus is provided with a hood and flue capable of removing the products of combustion to the open air.

6.3 Group 2 Refrigerants

6.3.1 *Direct Systems.* The maximum permissible quantity of a Group 2 *refrigerant* in a *direct system* is shown in Table 2. (Also see 6.1.2.)

TABLE 2. Maximum Permissible Quantities of Group 2 Refrigerants for Direct Systems*

Type of refrigerating system	*Maximum pounds for various occupancies** Institutional*	*Public assembly*	*Residential*	*Commercial*
Sealed Absorption Systems:				
a) In public *hallways* or *lobbies*	0	0	3	3
b) In other than public *hallways* or *lobbies*	0**	6	6	20
Self-Contained or Unit Systems:				
a) In public *hallways* or *lobbies*	0	0	0	0
b) In other than public *hallways* or *lobbies*	0	0**	6	20
Other *Refrigerating Systems* in *Machinery Room* (see 2.36)	0	0	300	600
Other *Refrigerating Systems* in *Class T Machinery Room* (see 2.37)	500	1000	No limit	No limit

**Direct systems* containing Group 2 *refrigerants shall not* be used for air conditioning for human comfort in Institutional, Public Assembly, and Residential Occupancies and *shall* be so used in Commercial Occupancies only when containing not more than 20 pounds of *refrigerant*.

**Six pounds allowed when installed in kitchens, laboratories, and mortuaries for applications other than air conditioning for human comfort.

6.3.2 *Indirect Systems.* The maximum permissible quantity of Group 2 *refrigerant* in an *indirect system* is shown in Table 3. Any system using a Group 2 *refrigerant* in excess of the quantities shown in Table 2 *shall* be of an *indirect* type as follows:

a) Institutional and Public Assembly Occupancies—*Indirect vented closed-surface*, or *double indirect vented open-spray.*

b) Residential and Commercial Occupancies—*Indirect vented closed-surface*, or *double indirect vented open-spray*, or *primary circuit of double-refrigerant* type.

6.3.2.1 *Machinery Rooms for Indirect Systems, Group 2 Refrigerants*

6.3.2.1.1 *Indirect systems* using Group 2 *refrigerants* not in excess of the quantities shown in Column 1 of Table 3 *shall* have all refrigerant-containing parts, excepting parts mounted outside the building, installed in a *machinery room* used for no other purpose than for mechanical equipment.

TABLE 3. Maximum Permissible Quantities of Group 2 Refrigerants for Indirect Systems

Occupancy	*Column 1* *Machinery Rooms (see 2.36), max lb*	*Column 2* *Class T Machinery Rooms (see 2.37), max lb*
Institutional	0	Not more than 500 lb
Public Assembly	0	Not more than 1000 lb
Residential	Not more than 300 lb	No limit
Commercial	Not more than 600 lb	No limit

6.3.2.1.2 *Indirect systems* using Group 2 *refrigerants* not in excess of the quantities shown in Column 2 of Table 3 *shall* have all refrigerant-containing parts installed in a *Class T machinery room.*

6.3.2.1.3 *Flame-Producing Devices, Hot Surfaces, and Electrical Equipment in Machinery Rooms.* Where a *machinery room* is required by this code to house a *refrigerating system* containing any Group 2 *refrigerant* other than sulphur dioxide, no flame-producing device or hot surface above 800 F *shall* be permitted in such room and all electrical equipment in the room *shall* conform to the requirements of Hazardous Locations Class I of the latest edition of the National Electrical Code (see Appendix 7). The use of matches, cigarette lighters, halide leak detectors, and similar devices *shall not* be considered a violation of this paragraph.

6.4 Group 3 Refrigerants

6.4.1 Group 3 *refrigerants shall not* be used in Institutional, Public Assembly, Residential, or Commercial Occupancies except in laboratories for Commercial Occupancies. In such laboratory installations only *unit systems* containinng not more than 6 pounds *shall* be used unless the number of persons does not exceed one person per 100 square feet of laboratory floor area, in which case the requirements for Industrial Occupancy *shall* apply.

Section 7. REQUIREMENTS FOR INDUSTRIAL OCCUPANCIES

7.1 General. There *shall* be no restriction on the quantity or kind of *refrigerant* used in an Industrial Occupancy, except as specified in 7.2 and 8.10.

7.2 Number of Persons. When the number of persons above the first floor exceeds one person per 100 square feet of floor area, the requirements of Commercial Occupancies *shall* apply unless that portion of the building containing more than one person per 100 square feet of floor area above the first floor, together with its *entrances* and *exits*, be cut off from the rest of the building by tight construction with self-closing, tight-fitting doors.

Section 8. INSTALLATION REQUIREMENTS

8.1 Foundations and Supports for *condensing units* or *compressor units shall* be of substantial and noncombustible construction when more than 6 inches high. (See 8.3.)

8.2 Moving Machinery *should* be guarded in accordance with accepted safety standards. (See Appendices 3 and 4.)

8.3 Clear Space adequate for inspection and servicing of *condensing units* or *compressor units shall* be provided.

8.4 Condensing Units or Compressor Units with Enclosures *shall* be readily accessible for servicing and inspection.

8.5 Water Supply and Discharge Connections *should* be made in accordance with accepted safety and health standards. (See Appendix 5.)

8.5.1 Discharge water lines *shall not* be directly connected to the waste or sewer system. The waste or discharge from such equipment *shall* be over and above a trapped and vented plumbing fixture.

8.6 Illumination adequate for inspection and servic ing of *condensing units* or *compressor units shoul* be provided. (See Appendix 6.)

8.7 Electrical Equipment and Wiring *shall* be installe in accordance with accepted safety standards (See Appendix 7.)

8.8 Gas Fuel Devices and Equipment used with *refrig erating systems shall* be installed in accordanc with accepted safety standards. (See Appendix 8.

8.9 Open Flames. When the quantity of flammabl *refrigerant* in any one *refrigerating system* exceed the amount given in Table 4 for each 1000 cubi feet of room volume in which the system or an part thereof is installed, then no flame-producin device or hot surface above 800 F *shall* be permit ted in such room and all electrical equipment in th room *shall* conform to the requirements of Ha ardous Locations Class I of the latest edition the National Electrical Code. (See Appendix 7.

TABLE 4. Maximum Permissible Quantities of Flammable Refrigerants

Name	*Chemical formula*	*Maximum quanti in lb per 1000 c ft of room volun*
Butane	C_4H_{10}	2½
Ethane	C_2H_6	2½
Ethyl chloride	C_2H_5Cl	6
Ethylene	C_2H_4	2
Isobutane	$(CH_3)_3CH$	2½
Methyl chloride	CH_3Cl	10
Methyl formate	$HCOOCH_3$	7
Propane	C_3H_8	2½

8.10 Flammable Refrigerants as listed in Table 4 *sh not* be used in a *refrigerating system* in a built- area in excess of 1000 pounds unless *approved* the authority having jurisdiction.

8.11 Machinery Room Requirements (see Definitio 2.36 and 2.37)

8.11.1 Each refrigerating *machinery room sh* be provided with tight-fitting door or doors a have no partitions or openings that will permit t passage of escaping *refrigerant* to other parts the building.

8.11.2 Each refrigerating *machinery room sh* be provided with means for ventilation to the ou air. The ventilation *shall* consist of windows doors opening to the outer air, of the size shown Table 5, or of mechanical means capable of rem ing the air from the room in accordance w Table 5. The amount of ventilation for *refrigera* removal purposes *shall* be determined by the *refr erant* content of the largest system in the *mach ery room.*

8.11.3 *Mechanical Ventilation,* when used, *shall* c sist of one or more power-driven exhaust fa which *shall* be capable of removing from the refr erating *machinery room* the amount of air spe fied in Table 5. The inlet to the fan, or fans, *air duct* connection *shall* be located near the refr

ating equipment. The outlet from the fan, or ns, or *air duct* connections *shall* terminate out-le of the building in an *approved* manner. When r *ducts* are used either on the inlet or discharge le of the fan, or fans, they *shall* have an area not ss than specified in Table 5. Provision *should* be ade for the inlet of air to replace that being hausted.

8.11.4 *Class T Machinery Rooms* in basements or b-basements (see Definition 2.37) *shall* have lequate mechanical ventilation operating continu-isly, which may be considered as a part of the nergency ventilation required in 8.11.2.

12 Air Duct Systems of air conditioning equipment r human comfort using mechanical refrigeration *ould* be installed in accordance with accepted fety standards. (See Appendix 9.)

TABLE 5. Minimum Air Duct Areas and Openings

Weight of refrigerant in system, lb	*Mechanical discharge of air, cfm*	*Duct area, sq ft*	*Open window or door area, sq ft*
to 20	150	¼	4
50	250	⅓	6
100	400	½	10
150	550	⅔	12½
200	680	⅔	14
250	800	1	15
300	900	1	17
400	1,100	1¼	20
500	1,275	1¼	22
600	1,450	1½	24
700	1,630	1½	26
800	1,800	2	28
900	1,950	2	30
1,000	2,050	2	31
1,250	2,250	2¼	33
1,500	2,500	2¼	37
1,750	2,700	2¼	38
2,000	2,900	2¼	40
2,500	3,300	2½	43
3,000	3,700	3	48
4,000	4,600	3¾	55
5,000	5,500	4½	62
6,000	6,300	5	68
7,000	7,200	5½	74
8,000	8,000	5¾	80
9,000	8,700	6¼	85
10,000	9,500	6½	90
12,000	10,900	7	100
14,000	12,200	7½	109
16,000	13,300	7¾	118
18,000	14,300	8	125
20,000	15,200	8¼	130
25,000	17,000	8¾	140
30,000	18,200	9	145
35,000	19,400	9¼	150
40,000	20,500	9½	155
45,000	21,500	9¾	160

Section 9. REFRIGERANT PIPING, VALVES, FITTINGS, AND RELATED PARTS

.1 General. *Refrigerant piping,* valves, fittings, and elated parts used in the construction and installation of *refrigerating systems shall* conform to the American Standard Code for Pressure Piping. (See Appendix 10.)

9.2 Metal Enclosures or Pipe Ducts for Soft Copper Tubing. Rigid or flexible metal enclosures *shall* be provided for soft, annealed copper tubing used for *refrigerant piping* erected on the premises and containing other than Group 1 *refrigerants.* No enclosures *shall* be required for connections between *condensing unit* and the nearest riser box, provided such connections do not exceed 6 feet in length.

9.3 Specific Minimum Requirements for Refrigerant Pipe and Tubing

9.3.1 Standard wall steel or wrought iron pipe may be used for *design working pressures* not exceeding 300 psig, provided lap-welded, electric resistance welded, or seamless pipe is used for sizes 2 inches and larger, and extra strong wall pipe is used for liquid lines for sizes 1½ inches and smaller conforming to American Standard B36.10-1939. (See Appendix 11.)

9.3.2 Standard iron pipe size copper and red brass (not less than 80 percent copper) pipe and tubing may be used and *shall* conform to the dimensions given in Tables II and IV of ASTM Specification B188-47T. (See Appendix 12.)

9.3.3 Watertube size hard copper tubing used for *refrigerant piping* erected on the premises *shall* conform to ASTM Specification B88-48, Types K or L (see Appendix 13), for dimensions and specifications. Copper tubing ¼ inch and ⅜ inch outside diameter having a minimum wall thickness of 0.025 inch and 0.030 inch, respectively, *shall* be considered as meeting the requirements for this copper tubing.

9.3.4 Soft annealed copper tubing used for *refrigerant piping* erected on the premises *shall not* be used in sizes larger than ⅞ inch outside diameter (¾ inch nominal). It *shall* conform to ASTM Specification B68-47 (see Appendix 14), and *shall* have wall thicknesses not less than contained in ASTM Specification B88-48 (see Appendix 13) for Type L. Copper tubing ¼ inch and ⅜ inch outside diameter having a minimum wall thickness of 0.025 inch and 0.030 inch, respectively, *shall* be considered as meeting the requirements for this copper tubing.

9.3.5 Soldered joints on copper tubing used in *refrigerating systems* containing Group 2 or Group 3 *refrigerants shall* be made with solders or alloys having melting points not less than 1000 F.

9.4 Joints and Refrigerant-Containing Parts in Air Ducts. Joints and all refrigerant-containing parts of a *refrigerating system* located in an *air duct* of an air conditioning system for human comfort *shall* be constructed to withstand, without leakage, a temperature of 1000 F.

9.5 Exposure of Refrigerant Pipe Joints. *Refrigerant* pipe joints *shall* be exposed to view for visual inspection, excepting when insulated or mechanically

protected, or when located in the cabinet of a *unit system,* or installed outside the building, or in a tight *pipe duct* or shaft vented to the outer air.

9.6 Stop Valves

9.6.1 *General Requirements.* All systems containing more than 50 pounds of a Group 1 *refrigerant* or 6 pounds of a Group 2 or 3 *refrigerant,* other than systems utilizing *nonpositive displacement compressors, shall* have *stop valves* installed as follows:

a) Each inlet of each *compressor, compressor unit,* or *condensing unit;*
b) Each discharge outlet of each *compressor, compressor unit,* or *condensing unit,* and of each *liquid receiver.*

9.6.2 *Systems Containing 100 Pounds or More of Refrigerant.* All systems containing 100 pounds or more of a *refrigerant,* other than systems utilizing *nonpositive displacement compressors, shall* have *stop valves,* in addition to those in 9.6.1, on each inlet of each *liquid receiver* and each branch liquid and suction line except that none *shall* be required on the inlet of a *receiver* in a *condensing unit* nor on the inlet of a *receiver* which is an integral part of a *condenser.*

9.6.3 *Stop valves* used with soft annealed copper tubing or hard drawn copper tubing ¾ inch nominal size or smaller *shall* be securely mounted, independent of tubing fastenings or supports.

9.6.4 *Stop valves shall* be suitably labelled if it is not obvious what they control. Numbers may be used to label the valves provided a key to the numbers is located near the valves.

9.7 Location of Refrigerant Piping

9.7.1 *Refrigerant piping* crossing an open space which affords passageway in any building *shall* be not less than 7½ feet above the floor unless against the ceiling of such space.

9.7.2 Free passageway *shall not* be obstructed by *refrigerant piping. Refrigerant piping shall not* be placed in any elevator, dumbwaiter, or other shaft containing a moving object, or in any shaft which has openings to living quarters or to main. *exit hallways. Refrigerant piping shall not* be placed in public *hallways, lobbies,* or stairways, except that such *refrigerant piping* may pass across a public *hallway* if there are no joints in the section in the public *hallway,* and provided nonferrous tubing of 1 inch nominal diameter (1⅛ inch outside diameter) and smaller be contained in a rigid metal pipe.

Section 10. DESIGN AND CONSTRUCTION OF EQUIPMENT

(Also see Section 11 for *pressure vessels*)

10.1 General

10.1.1 Every part of a *refrigerating system,* with the exception of pressure gages and control mechanisms, *shall* be designed, constructed, and assembled to withstand a test pressure not less than the minimum *refrigerant* leak field test pressure sp fied in Table 6 without being stressed beyond third of its ultimate strength. (See 10.2.)

NOTE: This paragraph establishes a minimum *de working pressure* in terms of the field test pressure so the minimum *refrigerant* leak field test pressure, spec in Table 6, can be safely applied. Rules governing *press relief devices, pressure-limiting devices,* etc., *shall* be b on the *design working pressure* selected.

10.1.2 All materials used in the construction installation of *refrigerating systems shall* be able for conveying the *refrigerant* used. No m rial *shall* be used that will deteriorate becaus the *refrigerant,* or the oil, or the combinatio both.

NOTE: Many *refrigerants* are corrosive to the usual terials when moisture or air, or both, are present and assumed in approving these materials that the system be charged and operated in accordance with accepted tice, to prevent or minimize this corrosion.

10.1.3 *Aluminum, Zinc, or Magnesium shall no* used in contact with methyl chloride in a *refri ating system.* Magnesium alloys *shall not* be in contact with any Freon *refrigerant.*

10.2 Minimum Test Pressures. Every refrigerant- taining part of every system, including pres gages and control mechanisms, *shall* be tested proved tight by the *manufacturer* at not less the minimum *refrigerant* leak field test press specified in Table 6. (See 10.3.)

10.3 Equipment Listed by an Approved Natio Recognized Testing Laboratory having a follow-u spection service *shall* be deemed as meeting intent of the requirements of 10.1 and 10.2. 1.2 and 2.3.1.)

10.4 Pressure-Limiting Devices

10.4.1 *Pressure-limiting devices shall* be prov on all systems containing more than 20 pounc *refrigerant* and operating above atmospheric sure, and on all water cooled systems so constr that the *compressor* or *generator* is capable of ducing a pressure in excess of the test pres except water cooled *unit systems* containin more than 3 pounds of a Group 1 *refrigerant,* viding the system will safely relieve the *refrig* in case of failure of the water supply or prov an overload device will stop the action of the *pressor* before the pressure exceeds one-fift ultimate strength of the system.

10.4.2 *Pressure-limiting devices shall* stop action of the *pressure-imposing element* at a sure not more than 90 percent of the *pres relief device* setting, or 90 percent of the *refr ant* leak field test pressure actually applied, w ever is lower. (See 10.2 for minimum *refrig* leak field test pressures.)

10.4.3 *Pressure-limiting devices shall* be nected, with no intervening *stop valves,* bet the *pressure-imposing element* and any *stop* on the discharge side.

10.5 Liquid Level Gage Glasses, except those o bull's-eye or reflex type, *shall* have automatic

ing shut-off valves, and such glasses *shall* be adequately protected against injury.

10.6 Dial of a Pressure Gage, when the gage is permanently installed on the *high side* of a *refrigerating system, shall* be graduated up to approximately double the operating pressure, but in no case less than 1.2 times the *design working pressure.*

10.7 Nameplate. Each separately sold *condensing unit* and each *compressor* or *compressor unit* sold for field assembly in a *refrigerating system shall* carry a nameplate marked with the *manufacturer's name,* nationally registered trademark or trade name, identification number, and the name of the *refrigerant* for which it is designed.

Section 11. REFRIGERANT-CONTAINING PRESSURE VESSELS

11.1 Refrigerant-Containing Pressure Vessels Exceeding 6 Inches in Diameter. Refrigerant-containing *pressure vessels,* except those having a maximum allowable internal or external working pressure 15 psig or less, irrespective of size, or having an inside diameter of 6 inches or less irrespective of pressure, *shall* comply with the rules of Section VIII of the 1949 Edition of the ASME Boiler Construction Code (see Appendix 15) covering the requirements for the design, fabrication, and inspection during construction of unfired *pressure vessels.*

11.1.1 *Code Inspection Exemption.* Unfired *pressure vessels* within the following volume and pressure limits are exempted from the inspection requirements of Paragraph U-65 of Section VIII of the 1949 Edition of the ASME Boiler Construction Code:

a) 5 cubic feet gross capacity or less designed for pressures not exceeding 250 psig;

b) 1½ cubic feet gross capacity or less designed for pressures exceeding 250 psig;

but such vessels *shall* otherwise comply with Section VIII of the 1949 Edition of the ASME Boiler Construction Code requirements, including the required stamping but omitting the code symbol. The foregoing limitations apply to each single vessel, and not to an assembly of vessels.

11.1.2 *Pressure Vessels Less Than 5 Cubic Feet Capacity.* Except as specified in 11.2, *pressure vessels* which are exempted in 11.1.1 from compliance with Paragraph U-65 of Section VIII of the 1949 Edition of the ASME Boiler Construction Code meet the requirements of Section 11 of this code, provided:

a) The details of design and construction *shall* conform with Section VIII of the 1949 Edition of the ASME Boiler Construction Code;

b) The materials of construction *shall* comply with the provisions of Section VIII of the 1949 Edition of the ASME Boiler Construction Code;

c) Welding operators and welding processes *shall* be qualified as provided for in Section VIII of the 1949 Edition of the ASME Boiler Construction Code;

d) Each vessel *shall* be tested and stamped in accordance with the Boiler Construction Code with either pneumatic or hydrostatic pressure in accordance with Par. U-77 (e);

e) The certification in 11.1.1 can be met by keeping a production series record of material used and tests made. Certification for individual vessels, where required, may be made by abstracting data from the series record by affidavit.

11.2 Refrigerant-Containing Pressure Vessels Not Exceeding an Inside Diameter of 6 Inches, irrespective of pressure, *shall* be listed either individually or as part of refrigeration equipment, by *an approved nationally recognized testing laboratory* having a follow-up inspection service. Vessels not so listed *shall* be constructed according to 11.1.2. (See 1.2 and 2.3.1.)

11.3 Safety Devices. All *pressure vessels,* irrespective of size or pressure, shall be equipped with safety devices in accordance with the requirements of Section 13 of this code.

11.4 Standard Hydrostatic Tests. Fusion welded *pressure vessels shall* be tested in accordance with Section VIII of the 1949 Edition of the ASME Boiler Construction Code. (See also 11.4.1.)

11.4.1 *Pneumatic Tests.* Vessels for use in services which cannot tolerate the presence of a testing liquid and which cannot be readily dried, and the parts of which have been previously tested by hydrostatic pressure to not less than 1½ times the *design working pressure* of the vessel, may be given a pneumatic test as prescribed in Paragraph U-64(f), Section VIII of the 1949 Edition of the ASME Boiler Construction Code.

Section 12. RELIEF DEVICES IN GENERAL

12.1 General. Every *refrigerating system shall* be protected by a *pressure-relief device* unless so constructed that pressure due to fire conditions will be safely relieved by *soldered joints,* lead gaskets, *fusible plugs,* or other parts of the system.

12.1.1 No *stop valve shall* be located between any automatic *pressure-relief device* or *fusible plug* and the part or parts of the system protected thereby, except when the parallel relief devices mentioned in 13.2 are so arranged that only one can be rendered inoperative at a time for testing or repair purposes.

12.1.2 All *pressure-relief devices shall* be connected as nearly as practicable directly to the *pressure vessel* or other parts of the system protected thereby, above the liquid *refrigerant* level, and installed so that they are readily accessible for inspection and repair and so that they cannot be readily rendered inoperative. *Fusible plugs* may be located above or below the liquid *refrigerant* level.

12.1.3 The seats and discs of *pressure-relief devices shall* be constructed of suitable material to

resist *refrigerant* corrosion or other chemical action caused by the *refrigerant.* Seats or discs of cast iron *shall not* be used.

12.1.4 The rated discharge capacity of a *pressure-relief valve* for a refrigerant-containing vessel, expressed in pounds of air per minute, *shall* be determined at a pressure at the inlet of the relief valve equal to 110 percent of the valve setting in accordance with Paragraph UG-131, Section VIII of the 1950 Edition of the ASME Boiler Construction Code. (See Appendix 16.)

12.1.5 The rated discharge capacity of a *rupture member* or *fusible plug* in pounds of air per minute *shall* be determined by the following formulas:

$$C = 0.6\ P_1 d^2 \qquad (1)$$

or

$$d = 1.29 \sqrt{\frac{C}{P_1}}$$

where C = minimum required discharge capacity, in lb of air per min

d = minimum diameter of bore of *fusible plug* or internal diameter of inlet pipe to *rupture member* in inches

For *rupture members:*

P_1 = bursting pressure, equal to *design working pressure,* except that for 13.7 the bursting pressure equals 1.20 times *design working pressure,* psig

For *fusible plugs:*

P_1 = saturation pressure, corresponding to the stamped temperature melting point of the *fusible plug* or the critical pressure of the *refrigerant* used, whichever is smaller, psig

12.1.6 All *pressure-relief devices* (not *fusible plugs*) *shall* be directly pressure-actuated.

12.1.7 The size of the discharge pipe from the *pressure-relief device shall* be not less than the size of the relief device outlet. The discharge from more than one relief device may be run into a common header, the area of which *shall* be not less than the sum of the areas of the pipes connected thereto.

12.1.8 The length of discharge *piping* permitted to be installed on the outlet of a relief valve, *rupture member,* or *fusible plug shall* be determined as follows:

$$C = \frac{3\ P\ d^{5/2}}{L^{1/2}} \qquad (2)$$

or

$$d = \sqrt[5]{\frac{C^2 L}{9P^2}}$$

where C = minimum required discharge capacity in lb of air per min

d = internal diameter of pipe in in.

L = length of discharge pipe in ft

P = $0.25P_1$ (P_1 is defined under Equation 1.)

(See Table 7 for computations derived from t preceding formula.)

12.2 **Pressure-Relief Devices for Positive Displaceme Compressors.** *Positive displacement compressors* o erating above 15 pounds per square inch gage a having a displacement exceeding 50 cubic feet p minute, *shall* be equipped by the *manufactur* with a *pressure-relief device* of adequate size a pressure setting to prevent rupture of the *compre sor,* located between the *compressor* and *stop val* on the discharge side. The discharge from su relief device may be vented to the atmosphere into the low pressure side of the system.

12.3 **Discharge of Pressure-Relief Devices and Fusi Plugs** on all systems containing more than 6 poun of *refrigerant,* other than systems containi Group 1 *refrigerants* in quantities less than sho in Table 1, Section 6, *shall* be to the outside of t building in an *approved* manner; *pressure-rel devices* may discharge into the *low side* of t system provided the relief devices are of a ty not appreciably affected by back pressures a provided the *low side* of the system is equipp with relief devices vented to the outside of t building in an *approved* manner.

12.4 **Ammonia Discharge.** Where ammonia is us the discharge may be into a tank of water wh *shall* be used for no purpose except ammonia sorption. At least 1 gallon of fresh water *shall* provided for each pound of ammonia in the syste The water used *shall* be prevented from freezi without the use of salt or chemicals. The ta *shall* be substantially constructed of not less th 1/8 inch or No. 11 U.S. gage iron or steel. horizontal dimension of the tank *shall* be grea than one-half the height. The tank *shall* ha hinged cover, or, if of the enclosed type, *shall* ha a vent hole at the top. All pipe connections s be through the top of the tank only. The discha pipe from the *pressure-relief valves shall* discha the ammonia in the center of the tank near e bottom.

12.5 **Sulphur Dioxide Discharge.** Where sulphur oxide is used, the discharge may be into a tank f absorptive *brine* which *shall* be used for no p pose except sulphur dioxide absorption. There s be 1 gallon of standard dichromate *brine* (pounds sodium dichromate per gallon of water) r each pound of sulphur dioxide in the system. *Bri s* made with caustic soda or soda ash may be u d in place of sodium dichromate, provided the qu tity and strength give the equivalent sulphur di ide absorbing power. The tank *shall* be subst tially constructed of not less than 1/8 inch or 11 U.S. gage iron or steel. The tank *shall* hav a hinged cover, or, if of the enclosed type, *shall* h e a vent hole at the top. All pipe connections s ll be through the top of the tank only. The discha e pipe from the *pressure-relief valve shall* discha e the sulphur dioxide in the center of the tank r r the bottom.

Section 13. RELIEF DEVICES FOR PRESSURE VESSELS

;.1 **General.** The rules of this section are based ɔon the rules given in Paragraphs UG-125 to G-134, inclusive, of Section VIII of the 1950 Edition of the ASME Boiler Construction Code, with ıch additional restrictions as are necessary for ɔntrol of *refrigerants.*

;.2 **Pressure Vessels over 5 Cubic Feet.** Each *pressure essel* containing liquid *refrigerant* with internal ross volume (gross capacity) exceeding 5 cubic eet and exceeding 6-inch inside diameter, except s specified in 13.4, and which may be shut off by alves from all other parts of a *refrigerating system, shall* be protected by an *approved pressure-elief valve* in parallel with a *rupture member* or econd *approved pressure-relief valve.* Each valve r *rupture member shall* be of sufficient capacity ɔ prevent the pressure from rising more than 10 ercent above the *design working pressure.* (See 2.1.1.)

13.2.1 *Relief Devices in Parallel on Large Vessels.* ı cases where large *pressure vessels* containing quid *refrigerant* except as specified in 13.4, reuire the use of two or more *pressure-relief devices* ı parallel to obtain the capacity required by 13.5, ıe battery of *pressure-relief devices shall* be conidered as a unit, and therefore as one *pressure-elief device.*

;.3 **Pressure Vessels with Gross Volume of 5 Cubic eet or Less.** Each *pressure vessel* having a gross olume of 5 cubic feet or less, containing liquid *efrigerant,* except as specified in 13.4, and which ıay be shut off by valves from all other parts of a *efrigerating system, shall* be protected by a *pressure-relief device,* or *fusible plug.* This *shall not* pply to vessels having an inside diameter of 6 ıches or less listed individually or as a part of efrigeration equipment by *an approved nationally ecognized testing laboratory* having a follow-up ıspection service. (See 1.2 and 2.3.1.) If a *fusible lug* is used, the ultimate bursting pressure of the essel so protected *shall* be at least 2½ times the *efrigerant* saturation pressure, psig, correspondıg to the stamped temperature on the *fusible plug,* r at least 2½ times the critical pressure of the *efrigerant* used, whichever is the smaller. A *usible plug* is permitted only on the *high side* of a *efrigerating* system.

;.4 **Relief Devices for Pressure Vessels Used as, or as art of, Evaporator.** Provisions of 13.2 and 13.2.1, rhich require a second parallel *approved* relief evice, and 13.3 do not apply to *pressure vessels* sed as, or as part of, *evaporators* insulated or ıstalled in an insulated space, and which may be hut off by valves from all other parts of a *refrigrating system.*

;.5 **Required Capacity.** The minimum required rated ischarge capacity of the *pressure-relief device* or *usible plug* for a refrigerant-containing vessel *hall* be determined by the following formula:

$$C = fDL \qquad \text{Equation 3}$$

where C = minimum required discharge capacity of the relief device in lb of air per min
D = outside diameter of the vessel in ft
L = length of the vessel in ft
f = factor dependent upon kind of *refrigerant*, as follows:

Kind of refrigerant	*Value of f*
Ammonia	0.5
Freon-12 and Freon-22	1.6
All other *refrigerants*	1.0

13.6 **Pressure-Relief Device Setting.** All *pressure-relief devices shall* be set to start to function at a pressure not to exceed the *design working pressure* of the vessel as determined by the *manufacturer* and stamped on the vessel or system.

13.7 **Rupture Member Setting When Used in Parallel with Relief Valves.** *Rupture members* used in parallel with *pressure-relief valves* on refrigerant-containing vessels *shall* function at a pressure not to exceed 20 percent above the *design working pressure* of the vessel.

13.8 **Other Rupture Member Setting.** All other *rupture members* used in lieu of, or in series with, a relief valve *shall* function at a pressure not to exceed the *design working pressure* of the vessel and the conditions of application *shall* conform to the requirements of Section VIII of the 1950 Edition of the ASME Boiler Construction Code.

13.9 **Marking of Relief Devices**

13.9.1 All *pressure-relief valves* for refrigerant-containing vessels *shall* be set and sealed by the *manufacturer.* Each relief valve *shall* be marked by the *manufacturer* with the data required in Paragraph UG-129 (a) of Section VIII of the 1950 Edition of the ASME Boiler Construction Code.

13.9.2 Each *rupture member* for refrigerant-containing *pressure vessels shall* be marked with the information required in Paragraph UG-129 (d) of Section VIII of the 1950 Edition of the ASME Boiler Construction Code.

Section 14. FIELD TESTS

14.1 **General.** Every refrigerant-containing part of every system that is erected on the premises, except *compressors, condensers, evaporators,* safety devices, pressure gages, and control mechanisms, that are factory tested, *shall* be tested and proved tight after complete installation, and before operation, at not less than the minimum *refrigerant* leak field test pressures shown in Table 6.

14.2 **Test Medium.** No oxygen or any combustible gas or combustible mixture of gases *shall* be used within the system for testing.

14.3 **Posting of Tests.** A dated declaration of test *should* be provided for all systems containing 50 lb or more of *refrigerant*, where required by 14.1. The declaration *should* be mounted in a frame, protected by glass, and posted in the *machinery room* and *should* give the name of the *refrigerant* and the field *refrigerant* leak test pres-

TABLE 6. Minimum Refrigerant Leak Field Test Pressures

Refrigerant name	*Chemical formula*	*Minimum field refrigerant leak test pressures, psig* — *High pressure side*	*Low pressure side*
Ammonia	NH_3	300	150
Butane	C_4H_{10}	95	50
Carbon dioxide	CO_2	1500	1000
Dichlorodifluoromethane (Freon-12)	CCl_2F_2	235	140
Dichloroethylene	$C_2H_2Cl_2$	30	30
Dichloromethane (Carrene No. 1) (Methylene chloride)	CH_2Cl_2	30	30
Dichloromonofluoromethane (Freon-21)	$CHCl_2F$	70	40
Dichlorotetrafluoroethane (Freon-114)	$C_2Cl_2F_4$	50	50
Ethane	C_2H_6	1200	700
Ethyl chloride	C_2H_5Cl	60	50
Ethylene	C_2H_4	1600	1200
Isobutane	$(CH_3)_3CH$	130	70
Methyl chloride	CH_3Cl	210	120
Methyl formate	$HCOOCH_3$	50	50
Monochlordifluoromethane (Freon-22)	$CHClF_2$	300	150
Propane	C_3H_8	300	150
Sulphur dioxide	SO_2	170	85
Trichloromonofluoromethane (Freon-11)	CCl_3F	30	30
Trichlorotrifluoroethane (Freon-113)	$C_2Cl_3F_3$	30	30

NOTES:

a) For *refrigerants* not listed in Table 6 the test pressure for the high pressure side *shall* be not less than the saturated vapor pressure of the *refrigerant* at 150 F. The test pressure for the low pressure side *shall* be not less than the saturated vapor pressure of the *refrigerant* at 110 F. In no case *shall* the test pressure be less than 30 psig.

b) When a *compressor* is used as a booster to obtain a low pressure and discharges into the suction line of another system, the booster *compressor* is considered a part of the *low side*, and values listed under the *low side* column in Table 6 *shall* be used for both *high* and *low side* of the booster *compressor* provided that a low pressure stage *compressor* of the *positive displacement* type *shall* have a *pressure relief valve*.

c) In field testing systems using *nonpositive displacement compressors*, the entire system *shall* be considered for field test purposes as the *low side* pressure.

sures applied to the *high side* and the *low side* of the system. The declaration of test *should* be signed by the installer and, if an inspector is present at the tests, he *should* also sign the declaration. When requested, copies of this declaration *shall* be furnished to the enforcing authority.

Section 15. INSTRUCTIONS

15.1 Signs. Each *refrigerating system* erected on the premises *shall* be provided with an easily legible permanent sign securely attached and easily accessible, indicating thereon the name and address of the installer, the kind and total number of pounds of *refrigerant* required in the system for normal operations, and the *refrigerant* leak t test pressure applied.

15.2 Metal Signs for Systems Containing More T 100 Pounds of Refrigerant. Systems containing m than 100 pounds of *refrigerant shall* be provi with metal signs having letters not less than inch in height designating the main shut-off va to each vessel, main steam or electrical cont remote control switch, and *pressure-limiting vice.* On all exposed high pressure and low p sure *piping* in each room where installed out the *machinery room*, shall be signs, as speci above, with the name of the *refrigerant* and letters "HP" or "LP".

15.3 New Sign for Changed Refrigerant. When kind of *refrigerant* is changed as provided in (Substitution of Refrigerant), there *shall* b new sign, of the same type as specified in 15.2, i cating clearly that a substitution has been m and stating the same information for the new *frigerant* as was stated in the original.

15.4 Charging and Discharging Refrigerants. W *refrigerant* is added to a system, except a *system* requiring less than 6 pounds of *refriger* it *shall* be charged into the low pressure sid the system. Any point on the downstream sid the main liquid line *stop valve shall* be consid as part of the low pressure side when opera with said *stop valve* in the closed position. service *container shall* be left connected to a sy except while charging or withdrawing *refrige*

15.5 Refrigerants Withdrawn from Refrigerating Sy *shall* be transferred to *approved containers* (See Appendix 2.) No *refrigerant shall* be charged to a sewer.

15.6 Containers Used for Refrigerant Withdrawn fr Refrigerating System *shall* be carefully weighed time they are used for this purpose, and the *tainers shall not* be filled in excess of the pe sible filling weight for such *containers* and *refrigerants* as are prescribed in the pertinen ulations of the Interstate Commerce Commi (See Appendix 2.)

15.7 Substitution of Kind of Refrigerant in a sy *shall not* be made without the permission of th proving authority, the user, and the makers o original equipment, and due observance of s requirements, including:

a) The effects of the substituted *refrigera* o materials in the system;

b) The possibility of overloading the *liqui* re *ceiver* which *should not* be more tha 8 percent full of liquid;

c) The liability of exceeding motor horsep e *design working pressure*, or any othe ment that would violate any of the prov of this code;

d) The proper size of *refrigerant* controls;

e) The effect on the operation and setti safety devices;

f) The possible hazards created by mixtu the original and the substituted *refrige*

Effect of the classification of the *refrigerant* as provided in this standard.

Refrigerant Stored in a Machinery Room *shall* be more than 20 percent of the normal *refrigerant* ...ged nor more than 300 pounds of the *refriger*-...in addition to the charge in the system and the ...*igerant* stored in a permanently attached *re*-...*r*, and then only in *approved* storage *con*-...*ers*. (See Appendix 2.)

Masks or Helmets. One mask or helmet *shall* be ...ided at a location convenient to the *machinery* ...*a* when an amount of a Group 2 *refrigerant* be-...n 100 and 1000 pounds, inclusive, is employed. ...ore than 1000 pounds of a Group 2 *refrigerant* ...employed, at least two masks or helmets *shall* ...rovided.

.9.1 Only complete helmets or masks marked as ...*oved* by the Bureau of Mines of the United ...es Department of the Interior and suitable for ...*refrigerant* employed *shall* be used and they ...*l* be kept in a suitable cabinet immediately out-... the *machinery room* or other *approved* acces-... location.

.9.2 Canisters or cartridges of helmets or masks ...*l* be renewed immediately after having been ...l or the seal broken and, if unused, must be ...wed at least once every two years. The date ...lling *shall* be marked thereon.

...) **Maintenance.** All *refrigerating systems shall* ...naintained by the user in a clean condition, ... from accumulations of oily dirt, waste, and ...r debris, and *shall* be kept readily accessible ...ll times.

...1 **Responsibility as to Operation of the System.** It ...*l* be the duty of the person in charge of the ...nises on which a *refrigerating system* contain-...more than 50 pounds of *refrigerant* is installed, ...lace a card conspicuously as near as practicable ...ne *refrigerant compressor* giving directions for ...operation of the system, including precautions ...e observed in case of a breakdown or leak as ...ws:

...) Instruction for shutting down the system in case of emergency;

...) The name, address, and day and night telephone numbers for obtaining service;

...) The name, address, and telephone number of the municipal inspection department having jurisdiction, and instructions to notify said department immediately in case of emergency.

...2 **Pressure Gages** *should* be checked for accuracy ...r to an air test and immediately after every ...sion of unusually high pressure, either by com-...ison with master gages or by setting the pointer ...determined by a deadweight pressure gage ...er.

TABLE 7. Length of Discharge Piping for Relief Valves or Rupture Members of Various Discharge Capacities

(Based on Equation 2, Paragraph 12.1.8. See also Paragraphs 13.2 to 13.7, inclusive.)

*Equiv. length of discharge pipe, ft (L)	Discharge capacity in lb of air per min (C) Standard wall iron pipe sizes, in.							
	½	¾	1	1¼	1½	2	2½	3
	RELIEF DEVICE SET AT 25 PSIG (P)							
50	0.81	1.6	2.9	5.9	8.7	16.3	25.3	43.8
75	0.67	1.4	2.4	4.9	7.2	13.3	20.9	35.8
100	0.58	1.2	2.1	4.2	6.2	11.5	18.0	30.9
150	0.47	0.95	1.7	3.4	5.0	9.4	14.6	25.3
200	0.41	0.8	1.5	2.9	4.4	8.1	12.6	21.8
300	0.33	0.67	1.2	2.4	3.6	6.6	10.5	17.9
	RELIEF DEVICE SET AT 50 PSIG (P)							
50	1.6	3.3	5.9	11.9	17.4	32.5	50.6	87.6
75	1.3	2.7	4.9	9.7	14.3	26.5	41.8	71.5
100	1.2	2.3	4.2	8.4	12.3	23.0	36.0	61.7
150	0.94	1.9	3.5	6.9	10.0	18.7	29.2	50.6
200	0.81	1.6	2.9	5.9	8.7	16.3	25.3	43.7
300	0.66	1.3	2.5	4.9	7.1	13.3	21.0	35.7
	RELIEF DEVICE SET AT 75 PSIG (P)							
50	2.4	4.9	8.9	17.9	26.1	48.7	75.9	131.5
75	2.0	4.1	7.3	14.6	21.4	39.8	62.6	107.0
100	1.7	3.5	6.4	12.6	18.5	34.4	54.0	92.6
150	1.4	2.8	5.2	10.3	15.0	28.0	43.8	75.9
200	1.2	2.5	4.4	8.9	13.1	24.4	37.9	65.6
300	0.9	2.0	3.7	7.3	10.7	19.9	31.5	53.5
	RELIEF DEVICE SET AT 100 PSIG (P)							
50	3.2	6.6	11.9	23.8	34.8	65.0	101.2	175.2
75	2.7	5.4	9.7	19.4	28.6	53.0	83.6	143.0
100	2.3	4.6	8.5	16.8	24.6	45.9	72.0	123.6
150	1.9	3.8	6.9	13.7	20.0	37.4	58.4	101.2
200	1.6	3.3	5.9	11.9	17.5	32.5	50.6	87.6
300	1.3	2.7	4.9	9.7	14.2	26.5	42.0	71.4
	RELIEF DEVICE SET AT 150 PSIG (P)							
50	4.9	9.9	17.9	35.7	52.3	97.5	151.8	262.8
75	4.0	8.1	14.6	29.2	42.9	79.5	125.4	214.5
100	3.5	6.9	12.7	25.2	36.9	68.9	108.0	185.4
150	2.8	5.7	10.4	20.6	30.0	56.1	87.6	151.8
200	2.4	4.9	8.9	17.8	26.2	48.7	75.9	131.4
300	1.9	4.0	7.4	14.6	21.1	39.7	63.0	107.1
	RELIEF DEVICE SET AT 200 PSIG (P)							
50	6.5	13.2	23.8	47.6	69.7	130.0	202.4	350.4
75	5.3	10.8	19.4	38.9	57.2	106.0	167.2	286.0
100	4.6	9.2	16.9	33.6	49.2	91.8	144.0	247.2
150	3.8	7.6	13.8	27.4	40.0	74.8	116.8	202.4
200	3.2	6.5	11.8	23.8	34.9	64.9	101.2	175.2
300	2.6	5.3	9.8	19.4	28.4	52.9	84	142.8
	RELIEF DEVICE SET AT 250 PSIG (P)							
50	8.1	16.5	[illegible]	59.5	87.1	162.5	253.0	484.0
75	6.7	13.5	24.3	48.6	71.5	132.5	209.0	357.5
100	5.8	11.6	21.2	42.0	61.6	114.8	180.0	309.0
150	4.7	9.5	17.3	34.3	[illegible]	93.5	146.0	253.0
200	4.1	8.2	14.8	29.7	[illegible]	81.2	126.5	219.0
300	3.3	6.7	12.3	24.3	35.5	66.2	[illegible]	[illegible]
	RELIEF DEVICE SET AT [illegible]00 PSIG (P)							
50	9.7	19.8	35.7	71.4	[illegible]	195.0	[illegible]	[illegible]
75	7.9	16.2	29.1	[illegible]	85.8	159.0	[illegible]	429.0
100	6.9	13.9	25.4	50.4	73.9	[illegible]	[illegible]	[illegible]
150	5.6	11.3	20.7	41.1	60.0	112.2	175.2	[illegible]
200	4.9	9.8	17.8	35.6	52.4	97.4	151.8	[illegible]
300	3.9	7.9	14.7	29.1	42.6	79.4	126.0	214.2

29-8. CAPILLARY TUBE REFRIGERANT CONTROLS*

The introduction of Freon-12 refrigerant together with the development of a successful hermetic compressor has made possible the prevalent use of the capillary tube as a device for controlling the flow of refrigerant to the lowside. Today practically all of the domestic refrigerators being built, and many of the smaller size package-type hermetic commercial refrigerating systems built by high mass production methods employ a capillary tube to the almost complete exclusion of the float valve, the expansion valve and other refrigerant metering devices.

ADVANTAGES OF THE CAPILLARY TUBE

The reason for this popularity with the manufacturers of package-type refrigerating systems is obvious when one considers the cost saving characteristics and other advantages of the capillary tube. The most outstanding characteristic of the capillary tube is its simplicity. It is simply a small diameter liquid line connecting the high side to the low side and is usually soldered to the suction line for heat exchange purposes. Because of the pressure drop caused by the length and the small bore of the tube, it controls the flow of refrigerant to the low side. This is a marvel of simplicity. There are no moving parts and the capillary is merely substituted for the conventional liquid line. In addition, the unloading characteristic of the capillary tube (1) reduces the amount of refrigerant charge required and makes possible the elimination of the liquid receiver and (2) permits the use of a split-phase hermetic motor compressor. Split-phase motor compressors are recommended for use only with a device such as a capillary that allows the lowside and highside pressures to equalize during the off cycle, thereby reducing the starting torque requirements of the motor.

These are compelling reasons for using a capillary tube whenever possible on a hermetic refrigerating system that is mass produced for a highly competive market.

*Courtesy of Universal Cooler Corp.

PRECAUTIONS NEEDED IN APPLYING CAPILLARY TUBE

The serviceman may often wish to convert an old refrigerating system from a float valve or expansion valve to a capillary tube in order to make possible the use of the split-phase hermetic compressor or condensing unit, or he may wish to replace some of the components of a system that already uses a capillary. In order to do this successfully in the field or service shop, extreme caution is necessary. In spite of the apparent simplicity of the capillary very careful balancing of the system is required to insure satisfactory performance. Improper balance of the system will be evidenced by excessive running time, abnormal operating pressures or by extreme difficulty in adjusting the refrigerant charge properly.

First, both the highside and lowside must be suitable for use with a capillary tube. Second, the capillary must be properly matched to the capacity of the condensing unit. Third, high standards of cleanliness and dehydration during processing are essential. Failure to take these factors into account will inevitably result in unsatisfactory performance and unless the serviceman is able and willing to do a good job he would do well to avoid the capillary tube completely.

THE FIRST STEP - DESIGN OF HIGHSIDE AND LOWSIDE

LOWSIDE APPLICATION

COND. UNIT	HIGH(30° F.)	MEDIUM(10° F.)	LOW(-10° F.)
	-	5' of 0.031",or	10' of 0.031",or
1/8 H.P.	5' of 0.036",or	9' of 0.036",or	20' of 0.036".
	8' of 0.042",or	18' of 0.042".	-
	16' of 0.049".	-	-
	-	-	8' of 0.031",or
1/5 H.P.	-	6' of 0.036",or	16' of 0.036".
	5' of 0.042",or	12' of 0.042".	-
	10' of 0.049".	-	-

29-19. Approximate capillary tube sizes.
(Tecumseh Products Corp.)

During certain portions of the operating cycle, the compressor may pump more than a capillary can pass. This will result in liquid refrigerant backing up in the highside. If a conventional receiver is used, most of the refrigerant will accumulate here; therefore, to prevent possible short charging of the lowside during portions of the operating cycle the conventional liquid receiver should be omitted. For this reason, capacitor-type units employing a receiver are not recommended for use with a capillary tube. In the event that a hermetic condensing unit is being reworked for capillary tube application, not only should the receiver be omitted but also all liquid traps in the highside should be avoided to insure rapid unloading of the highside during the off cycle of the compressor.

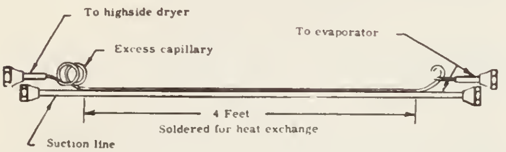
Design of the lowside is equally important. The lowside should be of the type that will satisfactorily operate on a comparatively small amount of refrigerant, preferably less than one pound, in order not to impose excessive loads on the condensing unit during pulldown. This is especially important because of the necessity of operating without a receiver. If the evaporator is of the dry type, a liquid accumulator will usually be required to allow for some variation in refrigerant charge.

Because of the relatively large refrigerant charge required by evaporators designed for use with the float valve, such evaporators are not usually suitable for capillary applications, therefore, it is not generally recommended that capillary tubes be applied to evaporators of this type unless the charge requirements are less than one pound refrigerant.

THE SECOND STEP - CAPILLARY SELECTION

Although good engineering practice demands that the proper capillary be determined by laboratory tests for each piece of equipment at standard operating conditions, this procedure is not practical from a serviceman's standpoint; however, as a result of numerous tests made by Universal Cooler, it is possible to recommend the approximate capillary tube to be used with the Universal Cooler 1/8 H.P. and 1/5 H.P. split-phase condensing units and compressors for the particular lowside application. Fig. 29-19 gives capillary recommendations in tabular form and enables one to choose a capillary tube best suited to the application. Approximately four feet of the capillary tube must be SOLDERED to the suction line to provide good heat exchange and to stabilize the metering action of the capillary tube. The remaining capillary should be coiled in the unit compartment.

These recommended lengths and bores are based on the assumption that a four foot section of the capillary will be soldered to the suction line as shown in the sketch, Fig. 29-20. Recommended lengths will not apply if this is not done or if certain patented prefabricated assemblies of equivalent flow resistance are used. Most satisfactory operation will be obtained if the recommendations in the table are followed rather than to work ''blindly'' with prefabricated capillaries or adjustable restriction devices.



29-20. A typical replacement capillary tube and suction line.
(Tecumseh Products Corp.)

Insufficient capillary will give poor overall efficiency due to the blowing of some uncondensed gas through the capillary; on the other hand, too much capillary will result in liquid refrigerant backing up in the high side, thus increasing the discharge pressure and short charging the low side. Thus, proper matching of the capillary to the compressor is essential to insure satisfactory performance of the system.

THE THIRD STEP - CAREFUL PROCESSING

It is obvious that extreme care must be taken to insure a dry, clean system. The hermetic condensing unit is bone dry and clean when it leaves the factory; however, it will be necessary to make sure that no moisture or dirt enters during the installation and that the rest of the refrigerating system is dry and clean before final assembly to the unit. As an additional precaution an approved high side drier incorporating a strainer must be located ahead of the capillary. The use of a commercial anti-freeze agent is not recommended and its use will void the warranty.

All air must be exhausted from the system before the final refrigerant charge is introduced. Inasmuch as most condensing units contain F-12 holding charge the recommended procedure is to blow the lowside and connecting lines free of air with a purge of F-12 before connecting to the highside. Then, before final charging, the system should be evacuated through the charging valve. If evacuating equipment is not available, the suction line flare connection at the valve should be left loose and the discharge service valve opened to allow the F-12 gas charge in the high side to sweep through the lines and lowside, purging any remaining air from the system.

Finally, the system must be charged with the proper amount of refrigerant. Unlike the float valve or expansion valve system which provides for continuous storage of surplus refrigerant in the highside, the capillary system is especially critical as regards refrigerant charge. The best method is to charge refrigerant slowly into the system with the unit running until frost forms on the suction line to a point just beyond the outlet of the evaporator. To avoid overcharging of the system, it is important that there be no refrigerant backed up in the high side during the final adjustment of the refrigerant charge.

This condition can be determined by noting the temperature difference between the first few and the last few rows of the condenser. If the last few rows are noticeably cooler to the touch you can feel sure that liquid refrigerant is backed up in the condenser, indicating either a restriction or poor selection of the capillary. The charge should then be checked later on after

the system has cycled to be sure this frost line is being maintained. If the system is overcharged, frost or heavy sweat will form on the suction line beyond this point. If the system is undercharged, frosting of the suction line or evaporator will cease somewhat ahead of that point. Another test to check the charge is to shut off the compressor for a few moments until the liquid refrigerant has drained from the highside and has passed out through the capillary to the lowside. If the system is properly charged there will be no indications of severe overcharge when the unit is restarted.

In summary, although the proper application of a capillary requires considerable design and test in the laboratory to achieve the best balanced system with maximum operating efficiency, it is possible for the service shop to make successful conversion to a capillary providing the serviceman is willing to follow the instructions outlined above, viz:

(1) Be sure that both the high side and the low side are properly designed for capillary application.

(2) Make the proper capillary selection.

(3) Process carefully to insure a clean, dry job properly charged with refrigerant.

UNLESS THE SERVICEMAN IS ABLE TO COMPLY WITH THE INSTRUCTIONS OUTLINED, CONVERSION TO OR REWORK OF A CAPILLARY SYSTYM IS NOT RECOMMENDED.

The data in Fig. 29-19 holds only if approximately four feet of capillary are soldered to the suction line to provide heat exchange and to stabilize the metering action of the capillary. The excess capillary, not used for heat exchange, should be coiled in the machine compartment as shown in Fig. 29-20.

29-9. SYSTEM FOR DETERMINING DRYNESS OF REFRIGERANTS *

The DFN Moisture Indicator Figure is 17-40, a laboratory test instrument for use as a production and Service tool. In a matter of minutes it shows the moisture vapor concentration in the refrigerant and the LOWEST TEMPERATURE at which the SYSTEM can be SAFELY OPERATED.

The INDICATOR CARTRIDGE contains DRIERITE, specially treated with coloring agent - GREEN when DRY - PURPLE when WET. The time required for the indicating crystals to change color determines the point at which the refrigerant or any gas will release water.

Any gas holding water in the vapor state, when cooled, will reach a temperature at which free moisture (Liquid water) will appear. The greater the concentration of water vapor in a gas, the higher the temperature at which water will be released. This freeing of moisture is readily shown by frost on cold lines, beads of water on glasses of cold liquids and in the refrigeration system by frozen expansion valves. Free water must be present before ice can be formed. The highest temperature at which free water is liberated, on cooling, is called the DEW POINT. For a given moisture concentration in a gas there is only one Dew Point temperature. Knowing the Dew Point of a refrigerant determines the lowest temperature at which the expansion valve will operate satisfactorily.

HOW DRY SHOULD THE SYSTEM BE?

A - To prevent the formation of sludges and plating - Dew Point should be -10 F. or lower.

B - To prevent valve freeze up it should have a dew point 5 F. lower than the suction temperature.

* McIntire Connector Co.

C - For safe operation the dew point must be - 10 F. or lower for all systems operating at a suction temperature of - 5 F. or above.
Where suction temperature is below - 5 F. the dew point must be 5 F. lower than the suction temperature.

INSTRUCTIONS

FOR ASSEMBLY AND OPERATION

ASSEMBLY

Assemble unit without cartridge as shown in Figure 17-42 using non-drying pipe compound on $\frac{1}{4}$ in. male pipe threads. Remove gauge port plug and purge out free oil lodged in port. Attach assembly to suction gauge if system is operating above 10 lb. back pressure. If operating below 10 lb. attach to discharge gauge port. Crack metering valve and allow gas to purge slowly through the unit for at least 20 seconds. Close metering valve. Put top felt in place, using tweezers, as moisture from the hands may contaminate it. Remove caps from indicator cartridge and install as shown. Hold wet finger tip $\frac{1}{2}$ in. above indicator cartridge and crack metering valve. If cold vapor can be felt sufficient gas is passing through cartridge.
CAUTION - Do not open metering valve further as liquid oil and/or refrigerant may be passed into the indicator cartridge and spoil it beyond use.

TEST

For checking systems operating at - 10 F. and above, watch crystals change to purple, shut metering valve and check time of test. Refer to chart below and you will find condition of the refrigerant. Leaving metering valve open to show added color just uses up the cartridge and does not prove anything. It is the time taken to start color change that counts.
FOR CHECKING SYSTEMS OPERATING BELOW - 10 F. - Blow into cartridge to give purple indication or take a partly used cartridge and install in indicator unit with purple coloring at the bottom. Crack valve, as stated above, and watch for the crystals to fade or pale out. When this starts close metering valve and check time. Refer to Fig. 29-21 to check condition of refrigerant.

	TIME MINUTES	REFRIGERANT DRY TO °F. DEW POINT
If green cartridge starts to show purple in the following time	1	20
	2	0
	4	-10
If purple in cartridge starts to fade in the following time	1/2	-60
	1	-50
	2	-40
	3	-30
No color changes either way	5	-15

29-21. Table of time intervals for color indication. (McIntyre Co.)

Fig. 29-21 is for new cartridges and varies slightly for cartridges that have been used.

Color change of the small particles in cotton should not be considered a true test. These minute particles are almost pure, indicating chemical and its color change does not provide an accurate indication of the moisture condition of the system. Moisture Indicator can be used in a like manner to check refrigerant in service drums, low sides and dry air for purging.

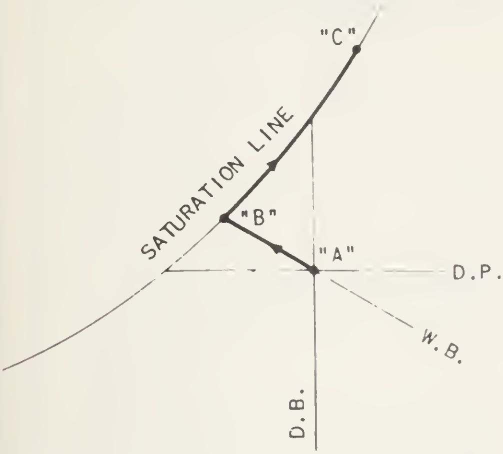
CAUTION

Mount indicator assembly vertical with

outlet at the top. Keep all parts as clean and dry as possible. Do not run test with cap on top as glass will not stand high pressure. By limiting test to a few grains indication, cartridge may be used several times if recapped and kept in a dry place.

Take assembly apart after test and flush out any oil which may have accumulated during test.

Indicator effective on Methyl Chloride and Freon gases. Do not use on Sulphur Dioxide or Ammonia.



29-22. Psychrometric behavior of the air in an evaporative condenser.
(Baltimore Aircoil Co., Inc.)

Check expansion valve to determine if it is installed in accordance with manufacturers' instructions.

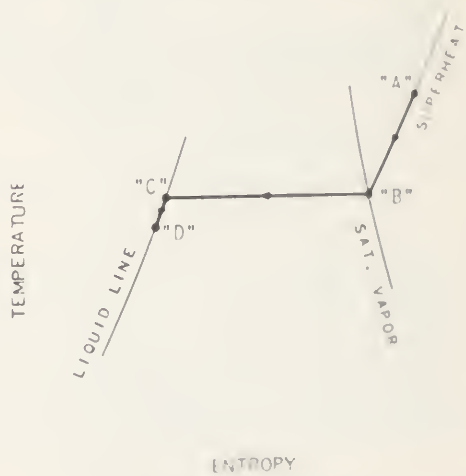
29-10. REFRIGERANT AND AIR CHANGES IN EVAPORATIVE CONDENSER

An evaporative condenser is described in Chapter 19. Such condensers are used because they provide lower head pressures than air cooled condensers and they use less water than water cooled condensers. As mentioned previously, they are popular where localities restrict the use of water for cooling purposes.

The evaporative condenser is based on the principle that one pound of water absorbs approximately 1000 Btu. per pound as it evaporates. This value compared to the specific heat of water of 1 Btu. per pound per F gives some indication of the water saving. Furthermore, the water evaporates into the air and the water cools to its wet bulb temperature, Fig. 29-22.

The air enters the evaporative condenser at (A) is cooled to temperature (B) but becomes saturated with moisture in the internal. The saturated air then travels over the condenser tubes against the water spray and exits at the blower at temperature (C). Note that (B) has a lower dry bulb than (A) and therefore the condenser temperatures and pressures are lower than if air at (A) were used for cooling only.

Fig. 29-23 shows the path of the refrigerant in the condenser tubes of the evaporative condenser. The gas enters



29-23. The heat content, the pressure and the temperature change of the refrigerant as it passes through an evaporation condenser.
(Baltimore Aircoil Co., Inc.)

the condenser at (A) in a superheated condition. The gas cools to the saturat-

ed vapor line and then condenses along line (B) to (C). The final cooling to the room or ambient temperature takes place (E) to (D). The line (B) to (C) would be at a higher temperature if the condenser were air cooled.

29-11. HEAT CONDUCTIVITY

CONDUCTIVITY
Miscellaneous Substances

Material	K
Air	.175
Concrete wall	8.00
Glass	5.0
Lead	243.0
Vacuum, high	.004

(Courtesy of: American Society of Refrigerating Engineers)

HEAT CONDUCTIVITY
Miscellaneous insulating Materials

Material	Density #/cu. ft.	K Conductivity
Cork, granulated, impregnated with pitch	17.79	0.428
Balsa	7.05	0.32
Glass wool (curled pyrex)	4.0	0.29
Mineral (slag) wool, loose packed	12.0	0.26
Rock wool (fibrous rock, also felted)	6.0	0.26
Sawdust, pine	1.56	0.57
Straw fibres, pressed	8.67	0.32
Wood fibres (kingia australis)	8.4	0.33
Wool, pure	4.99	0.26

Note: K=BTU/sq. ft./hr./°F. for a 1" thickness

(Courtesy of: American Society of Refrigerating Engineers)

CONDUCTIVITY OF PROPRIETARY MATERIALS

Trade Name	Density #/cu. ft.	K Conductivity
Armstrong's Corkboard	7.3	0.285
Celotex	13.2	0.31
Dry-Zero	1.0	0.24
Nu Wood	15.0	0.32
United's 100% pure Corkboard	9.0	0.27
U. S. Mineral Wool	12.0	0.26
Ferro Therm metal sheet(4 sheets)	4oz./□'/sheet	0.226

(Courtesy of: American Society of Refrigerating Engineers)

29-12. BRINE FREEZING TEMPERATURES

ALCOHOL (Formula No. 1)

Temperature °F. (Freezing)	10°	0°	−10°	−20°
Specific Gravity at 60°F.	.9691	.9592	.9486	.9345

GLYCERIN

Temperature °F. (Freezing)	20°	10°	0°	−10°	−20°	−30°
Specific Gravity at 60°F.	1.056	1.082	1.105	1.123	1.137	1.151

CALCIUM CHLORIDE

Temperature °F. (Freezing)	20°	10°	0°	−10°	−20°
Specific Gravity at 60°F.	1.090	1.140	1.175	1.201	1.227

29-13. SEALING INSULATIONS

The most serious problem with any insulation is to keep the insulation dry. The moisture that can collect in insulation is always present in the air. When the air on one side of a structure is more moist than on the other, the pressure difference (vapor pressure) is quite high. The moisture will then seek its way through the smallest opening and then condense in the colder area if the temperature is below the dew point temperature.

It is most important therefore to install a vapor seal on the warm side of the wall and also to allow any moisture that does get into the insulation to easily reach the cooling coil.

29-14. THERMO ELECTRIC REFRIGERATION

One explanation of why direct current electrical flow from one conductor to another of a different material will produce a lower temperature, is that as electrons flow from a more active atom to a lower activity atom, these electrons must slow up and in the act of slowing down release energy in the form of heat. Therefore electrons which flow from a lower activity atom to a higher activity atom must speed up. While doing this, the electron acquires energy (absorbs heat) and the joint becomes cooler. These connections are called hot junctions and cold junctions.

When electricity is passed through these materials to produce temperature changes it is called the Peletier effect.

When heat is applied to such a junction of unlike materials the electrical flow (or electrical unbalance) is called the Seebeck effect.

It has been discovered that some materials which are not classified as good conductors (semi-conductors) give better results in producing thermo electric refrigeration than do materials which are classified as good conductors.

It is understood then that electron flow is both electrical energy flow and heat flow.

ANSWERS TO REVIEW QUESTIONS

1-49. ANSWERS TO PROBLEMS AND QUESTIONS

1. 10.7 pounds per square inch Absolute.
2. 9.43 cubic inches.
3. 135 pounds per square inch gauge.
4. 150 cubic inches.
5. 970 Btu.
6. 58.46 pounds of sulphur dioxide.
7. 2.7 inches of vacuum.
8. 11 pounds per square inch or 22 inches of mercury.
9. 17.5 pounds per square inch Absolute.
10. 1668 pound gauge.
11. 42 F. to 45 F.
12. The pressure exerted upon it.
13. 0 pounds per square foot gauge or 2116.8 pounds per square foot Absolute.
14. Below.
15. It is solidified carbon dioxide.
16. No, because it will create a pressure up to 1000 pounds per square inch gauge if sealed in and would burst any ordinary container.
17. Dry ice will absorb a little more than twice the heat water ice will.
18. Yes, dark colors absorb more and radiate more than bright colors.
19. A house being heated by a hot air furnace.
20. Copper is a much faster conductor of heat.

2-52. ANSWERS TO REVIEW QUESTIONS

1. From the gauge: 1/8 FP x 1/4 MF adapter, 1/4 flare nut, 1/4 tubing, 1/4 flare nut, 1/4 MF x 1/4 MP.
2. The tubing should be cut square, and all chips and burrs should be removed.
3. The 1/4 in. uses 7/16 in. threads; the 3/8 in. uses ____ threads; and the 1/2 in. uses ____ threads.
4. Copper tubing usually has a .035 in. wall thickness although .032 in. thickness tubing is approved for some uses. The I.D. for 1/4 in. O.D. tubing is therefore .250 − (.035+.035) = .250 −.070 = .180 inches.
5. Working copper hardens it because the grains slip on each other making it more difficult to bend (slip bands).
6. The copper tubing end is frequently filed to remove the burr and to provide full wall thickness of the tubing at the end.
7. Twist the spring to increase its diameter.
8. No. Flux only keeps metal clean and from oxidizing. The metal must be cleaned by clean tools (scrapers, sandpaper, steel wool, etc.)
9. The metal must be heated to slightly above the melting temperature of the solder.
10. To remove the flux which would otherwise corrode the joint and also injure the inside of the refrigerating system.
11. The brazing flux becomes clear and transparent.
12. One should always use a 12 point socket if possible.
13. It is always considered safer to pull on a wrench.
14. By using a special 45 degree flare reamer.
15. Put the thermometer in an ice and water mixture (distilled

water). The thermometer should read 32 F.

16. The compound gauge is to enable one to read pressures either below or above atmospheric pressure. It is used for measuring evaporating pressures.
17. If there is an appreciable amount of wax, this wax will separate at the refrigerant orifice; and it will tend to clog same.
18. Never fill the cylinder more than 80 per cent full of liquid refrigerant; otherwise the cylinder may burst from hydraulic pressure.
19. A double cut file is used for rapid rough filing. It has two rows of file teeth across the face.
20. 1, End wrench, 2. Swivel handle, ratchet socket, 3. Box wrench, 4. Sliding - T handle, 5. Ratchet handle and socket, 6. Extension and ratchet, 7. Torque handle, 8. Pin punch, 9. Flex handle, 10. Sliding - T handle, 11. Phillips head screw driver, 12. Combination box and open end wrench, 13. Slim nose pliers, 14. Box wrench, 15. Cold chisels, 16. Combination pliers, 17. Universal joints, 18. End wrench.

3-24. ANSWERS TO REVIEW QUESTIONS

1. Five.
2. (1) Compressor, (2) condenser, (3) liquid receiver, (4) liquid line, (5) refrigerant control, (6) cooling unit, (7) motor control, (8) suction line.
3. (1) Cooling unit, (2) motor control, and (3) suction line.
4. (1) Compressor, (2) condenser, (3) liquid receiver, (4) liquid line.
5. (1) Reciprocating, (2) rotary, (3) gear, (4) centrifugal.
6. Hermetic or semi-hermetic.
7. As a gas is compressed the molecules are hit by the compressing device and thus travel faster, which is the meaning of a higher temperature.
8. To keep the high pressure from backing up into the cooling coil.
9. To enable the heat to be removed from the condenser efficiently.
10. A dry cooling coil.
11. The motor control.
12. (1) Automatic expansion valve, (2) thermostic expansion valve, (3) capillary tube, (4) low pressure side float, and (5) high-pressure side float.
13. The eccentric crankshaft has a larger bearing area and runs smoother.
14. .0001 inch to .0005 inch.
15. Very small, .010 inch to .020 inch clearance is allowed.
16. Approximately .010 inch to .015 inch.
17. A low side float maintains a constant level of liquid refrigerant on the low pressure side or one may say it maintains a constant quantity of liquid refrigerant on the low pressure side.
18. The expansion valve maintains a constant pressure on the low pressure side while the compressor is running.
19. The high side float maintains a constant level of liquid refrigerant on the high pressure side.
20. The purpose of the crankshaft seal is to make the joint, where a crankshaft enters the compressor, leak proof.
21. Another word for evaporation of a liquid is boiling or vaporizing.
22. Copper tubing or steel tubing is used for refrigerant lines.
23. The capillary tube reduces the pressure by offering a resistance to the flow of liquid.
24. The condensing pressure stops rising when the condenser condenses a number of molecules

equal to the number pumped into it.

25. A low pressure and liquid refrigerant must both be present to produce refrigeration.

4-31. ANSWERS TO REVIEW QUESTIONS

1. The compressor moves the evaporated gas to high temperature --high pressure level where the gas may then be easily cooled and converted to a liquid.
2. The compressor will be more compact and smoother.
3. A full floating piston is free to turn in either the piston bosses or in the connecting rod bushing.
4. The weight of the valves interferes with the gas flow; therefore the lighter they are, the better.
5. A soft metal to a hard metal polished surface in rubbing contact forms a leak proof joint.
6. Pistons are most commonly made of cast iron.
7. Any gas left in the cylinder at the end of the exhaust stroke is lost gas pumped and reduces the gas volume capacity of the compressor.
8. The compressor cylinder may be cooled by air, or water or both.
9. The motor and compressor assembly is mounted on springs inside of the sealing dome.
10. Hermetic motors are either cooled by pressing the stator in the dome to allow heat to flow to the dome, or the evaporated and cool gas is made to pass over the coils before it is picked up by the compressor.
11. No, it is not. It reciprocates in its slot.
12. Four of each.
13. The accuracy of the fit between the roller and the cylinder depends completely on the accuracy of the main bearing fits.
14. Nothing. It does have a check valve in the suction line to prevent the movement of oil and hot gas back into the cooling unit during the off cycle.
15. The cavity near the axis of the shaft can be used as an oil pump as the blade moves in and out of its slot.
16. Yes. The Norge Rollator used this type seal for years.
17. The blades are made of carbon to reduce weight and noise. The carbon also has a self lubricating quality and is very fast seating to provide a more efficient compressor.
18. If the compressor shaft is bent, the journals will not align themselves with the main bearings and will wear rapidly; the seal will leak very soon; and the clearance pockets if not the fits of the pumping parts will not be correct.
19. No. The compressor works on the principle of centrifugal force and valves are not necessary.
20. It revolves at a higher speed because the efficiency increases as the speed is increased.

5-28. ANSWERS TO REVIEW QUESTIONS

1. Float calibration is to have the needle close at a definite float level or position.
2. Four. Atmosphere pressure, low side pressure, adjusting spring, force, and needle return spring force.
3. To enable the same valve to be used for different refrigerants and also to adjust for different altitudes.
4. The low side float system, the automatic expansion valve, and the thermostatic expansion valve are the ones that can use a varying refrigerant charge.

5. Thermostatic expansion valve superheat is that temperature difference between the liquid refrigerant in the cooling coil and the thermal bulb temperature.
6. Approximately 20%. This amount evaporates and cools the remaining 80% liquid to cooling unit temperatures.
7. This charge must be the same refrigerant as that used in the system, to insure a constant superheat.
8. Between a 60 and 100-mesh screen.
9. In the late 1920's.
10. Brass.
11. The thermal bulb will not be able to react in time to keep a constant superheat, and the unit will frost back and starve intermittently.
12. It is usually fastened by means of an SAE flare connection although large units use a soldered joint and flange.
13. To aid the removal of oil that collects there.
14. It is a needle and seat combination, removable in one piece.
15. Either by bending the float arm or by using an adjusting screw provided.
16. Usually steel, but occasionally brass.
17. Excessive head pressure.
18. Either a weight check valve is used at the cooling unit end of the liquid line or a capillary tube carries the refrigerant to the coiling coil. In either case this tubing is insulated.
19. To permit the proper amount of refrigerant as the unit runs and to reduce the refrigerant pressure from the high pressure level to the low pressure level.
20. It reduces the pressure by friction, first of the liquid refrigerant, and then of the liquid and gas in combustion.
21. No, because all the refrigerant moves into the low side during the off-cycle.
22. The resistance increases as the tube length is increased and the amount of refrigerant flowing will decrease.
23. Yes, it is very important that the refrigerant be cleaned of any foreign matter before the refrigerant enters the tube.
24. Yes, by winding the tube in a tighter helix or by changing the cross section of the tube.
25. Rotary compressor systems.

6-27. ANSWERS TO REVIEW QUESTIONS

1. The thermostatic motor control, because a pressure motor control cannot operate with a constant low side pressure.
2. Because they both operate from changing pressures.
3. It maintains a useful temperature in a cabinet, and it controls the cycling intervals of the mechanism.
4. There are three.
5. Any volatile fluid.
6. An external switch must be provided to disconnect the starting winding after the motor comes up to speed.
7. The range adjustment affects the temperature of the coil and therefore the fixture.
8. The differential adjustment controls the cycling interval.
9. Various types of heat responsive switches are put in the circuit. These switches will open if the unit draws too much current, or if the compressor or motor gets too hot.
10. No.
11. Yes.
12. Yes.

13. Magnetic switch or magnetic starter.
14. Three.
15. A screwdriver with special provisions for holding the screw while it is being inserted.
16. By using a special tool which incorporates a refrigerant tube, a thermometer and a thermostat bulb clamp.
17. A device must be used to disconnect the starting winding when the motor reaches a safe speed, and this device usually mounted outside the hermetic dome.
18. Voltage drop is that amount of voltage lost overcoming the resistance to the current flow in any wire or electrical device.
19. The resistance of the loose connection acts as a heating coil, and the connection becomes warm or even hot enough to cause combustion.
20. The amperage magnetic relay has the larger wire in the coil.
21. No. It does not use gravity in its functions but relies on spring tension.
22. A fine mill file or dry sand paper.
23. To help trace circuits and to aid following the instructions on a wiring diagram.
24. The current draw or flow would be greater on starting.
25. The voltage drop is greatest as the motor is starting.

7-60. ANSWERS TO REVIEW QUESTIONS

1. Open systems are repulsion-start induction run motors, capacitors start induction motors and D.C. motors. Hermetic systems use split phase motors and capacitor start induction run motors.
2. This type motor uses two field windings.
3. To aid cooling and to prevent insulation breakdown.
4. No.
5. The motor starts as a repulsion-induction motor and runs as an induction motor.
6. Radical type commutators that look like spokes of a wheel and the cylindrical type that look like a straight barrel with staves.
7. Running winding - 108 watts to 163 watts.
8. When it is large enough for the starting current, it is too big for the running current.
9. It has fewer moving parts and therefore maintenance is less.
10. Open motors using plain bearings should be oiled about once each six months.
11. To absorb vibrations and to absorb some of the starting torque reaction.
12. Either split-phase or capacitor start-induction run motors.
13. Direct current motors are available in 32, 115 or 230 volt models.
14. Radio interference can be reduced by grounding the motor and compressor together and then grounding the motor to a conduct or water pipe.
15. Three.
16. Two.
17. Because the starting winding is constructed of finer wire and the current takes a little longer to build up its magnetism in the starter windings. Therefore, the result is like splitting the phase cycle.
18. Cooling the motor.
19. They must be specially insulated, because they operate in an oil and refrigerant atmosphere.
20. A synthetic rubber that is resistant to oil and refrigerant.
21. A capacitor is an electrical device made of two layers of metal

foil insulated from each other. It is used to absorb charges of electrons and discharge them at the current time.

22. Yes.
23. The starting circuit is opened.
24. Induction motors with shaded pole starting devices.
25. In parallel and controlled by the thermostat.
26. To free a stuck compressor. This method is successful where a foreign particle locks the compressor temporarily.
27. A powered test light will reveal continuity through the capacitor.
28. Voltage drop is the electrical loss that occurs in any and every electrical device when current flows.
29. Not more than 10% or about 15 volts.
30. Most wires have different colored insulations. If not, each wire should be tagged.
31. The magnetic center is the position a rotor tries to assume along its axis.
32. Electrical continuity is a closed circuit. There is a circuit for the electrical current to move along.
33. A compound wound D.C. motor has one field winding in parallel with the rotor windings and one field winding is in series with the rotor windings.
34. $\frac{1}{120}$ of a second.
35. To carry oil from the oil reservoir to the bearing surfaces (with capillary action).

8-38. ANSWERS TO REVIEW QUESTIONS

1. Because it has an obnoxious odor, it has too high a head pressure for air cooled condenser, and it is explosive and flammable in narrow limits.
2. By using a swab saturated with 28 per cent aqua ammonia: a white vapor will indicate the pressure of sulphur dioxide.
3. It is too flammable.
4. 75 pounds per square inch.
5. Soap suds are best for safety but a halide torch can be used in very well ventilated places.
6. At 5 F. sulphur dioxide has a vapor pressure of 6 inch vacuum and methyl chloride a pressure of 6 psig.
7. It means that those gases belonging to the halogen family can be detected by this method.
8. Toxic means that the material has a determined effect on the respiratory system.
9. The Grunow used to use Carrene.
10. It must be as moisture free as possible, it must have a 150 viscosity, it must be wax free and it must have a -20 F. pour point.
11. The same as sulphur dioxide but it need not be as moisture free.
12. It is known as dichlorodifluoromethane.
13. 108 psig.
14. 30 F.
15. 310 psig.
16. No.
17. Add about 35 F. to the room or ambient temperature and then look up the vapor pressure at this higher temperature.
18. Crosley in 1935.
19. Any refrigerant that contains a chemical of the halogen family. Those refrigerants with chlorine and/or fluorine are the most common ones.
20. The condensing temperature will be about 110 F. and the pressure will therefore be about 8 psig.
21. 220 psig.
22. They become equal when the unit is idle but the refrigerant becomes between 5 F. to 10 F.

colder than the coil when the unit is running.

23. The head pressure becomes higher than normal because the refrigerant still has to reach its condensing temperature and the air pressure is an added pressure to this condensing pressure and temperature.

9-37. ANSWERS TO REVIEW QUESTIONS

1. To keep the heat leakage into the cabinet to a minimum and therefore to reduce the cost of operation.
2. Approximately 3 inches.
3. Because the inside temperature of the cabinet is cold enough to make moisture precipitate out of the air. If the insulation is not water proof, the moisture will collect in it and ruin its insulating ability.
4. This is the cubic feet of space in which food may be stored.
5. (1) In the top of the cabinet, (2) in the base of the cabinet, and (3) remote.
6. To enable an easy means of breaking the frozen contact between the tray and the shelf.
7. The frost acts as an insulation and also stores food odors.
8. Approximately 1/4 inch.
9. A luke warm baking soda and water solution.
10. By washing them with vinegar.
11. (1) Corkboard, (2) dry-zero, and (3) metal foil.
12. By means of a rubber gasket which is slightly compressed when the cabinet door is closed, sealing it.
13. (1) Upper right hand corner, (2) upper left hand corner, (3) upper middle, and (4) across the top of the cabinet.
14. Because warm air rises and cold air falls, the location of cooling coil at the top of the cabinet promotes air circulation and uniform temperature.
15. The very cold cooling coil will draw the moisture out of foods (dehydrate) unless they are protected.
16. Because a blast of air is continually forced over the air-cooled condensers in most machines, this air circulation deposits dust and lint between the fins of the condensers. This dirt accumulates and eventually restricts the air flow over the condenser to such an extent that very inefficient cooling results.
17. A distributor of electrical refrigerators should operate each and every refrigerator for 24 hours, checking it thoroughly for correct functioning, before delivering it to the purchaser.
18. A good method for providing positive rear ventilation of a base located condensing unit is to attach strips of wood or metal to the rear of the cabinet in such a manner that the cabinet cannot be pushed tight against the wall.
19. If a refrigerating mechanism is shut down for 48 hours or more the pressures in the system equalize and become the pressure corresponding to the room temperature. The result of this is that condensation of refrigerant will take place in the crankcase of the compressor, and when the unit is started again in addition to having an over-loaded compressor because of the excessive low side pressures the liquid refrigerant vaporizing in the crankcase emulsifies the oil. These two conditions occasionally break down the machine, and the reason for this is the stirring up of the complete system to the

extent that any dirt particles which may have settled in the screen and odd crevices will again be in circulation.

20. It is best to allow a refrigerating machine to refrigerate continuously for its full life and never allow it to be turned off for more than 6 hour periods. This enables the machine to settle down to one continuous routine and permits a harmonic operation of all of the various parts of the system. It is the best insurance for a long continuous and efficient life of the mechanism.
21. To allow correct oil levels, and to permit correct operation of the float mechanisms.
22. Low line voltage operation will result in very poor operating efficiencies and burned-out motors.
23. It is drained to a pan near the compressor when the heat from the condensing unit evaporates it.
24. Place a bright light inside the refrigerator cabinet and look for light through cracks in the gasket seal.
25. Strikes only are adjustable in most cases. Strikes are mounted on adjustable bases.

10-15. ANSWERS TO REVIEW QUESTIONS

1. The condenser cooling fan is driven by the same motor that drives the compressor.
2. The weight valve is used to keep the liquid line pressure high enough to prevent evaporation of the refrigerant in the liquid line.
3. The low side float needs too much room and too much refrigerant.
4. Not all condensers. Most of the newer units are designed to provide natural connections past the condenser.
5. Some of the very first units built in the early 20's did use a pressure motor control.
6. Yes, a few were used when conventional systems were popular.
7. The low side float systems mainly used sulphur dioxide although a few used methyl chloride.
8. The first use of the capillary tube was in the Rice refrigerator in 1928.
9. No, many refrigerators had the condensing unit located in the top of the cabinet.
10. The capillary tube prevented sweating or frosting of the liquid line between the float and the cooling coil.

11-58. ANSWERS TO REVIEW QUESTIONS

1. In air-cooled units a hot liquid line indicates a lack of refrigerant in the system.
2. Most of the units have service valve stems which use a 1/4 in. square opening wrench. Some of the companies, however, use a 3/16 in. square opening wrench.
3. Controls are tested with dry air to eliminate the condensation of moisture on the internal parts of the mechanism.
4. A pounding noise in the compressor when the compressor starts to pump a vacuum is indicative of oil pumping. (This is hard on the compressor and the compressor should be stopped.)
5. After gauges have been installed in the system, they should be carefully tested for leaks because (1) in case the low side is under a vacuum, a leak will permit the air to go into the system; (2) if the pressure in the system is higher than atmospheric pres-

sure the refrigerant will leak out and be irritating to the service man if it is an irritant refrigerant, while in all cases it will make it difficult for the service man to detect the exact source of permanent leaks in the system; (3) the leakage of refrigerant at the gauge joints occasionally spoils the accuracy of the gauge reading.

6. A halide torch must be charged and pumped up to its pressure outside the rooms where the refrigerating mechanism is located because if any refrigerant is put into the torch either through the medium of air or by means of the fluid itself, the torch will burn continuously with the leak detecting color destroying its usefulness. If this has been done the torch must be thoroughly cleaned to make it usable again.
7. Service valve packings are made of asbestos covered with lead sheet and graphite.
8. An exhaust valve seat is best lapped on a lapping block, first using a fine alundum lapping powder and refrigerant oil. A figure eight motion should be used and the valve plate should be continuously turned under one's hand. Remove all the lapping powder and clean both the block and the valve plate with oil after all the crevices have been removed from the valve seat and then polish the same by lapping it on the same block but using refrigerant oil only.
9. An air-cooled sulphur dioxide system having 110 psi head pressure indicates the following troubles in the order of their possibility:
   (1) Air in the system.
   (2) Externally restricted condenser.
   (3) Poor circulation of air in or out of the condensing unit.
   (4) Too much refrigerant in the system.
   (5) Too much oil in the system.
   (6) An extremely warm room.
10. A frosted suction line with an above normal low side pressure indicates:
    (1) With an expansion valve refrigerant control this means that the expansion valve adjustment is turned in too far or that the needle and seat are leaking.
    (2) With low side float system this means that the needle and seat are leaking or that the float is calibrated too high, or that the float ball itself has sprung a leak.
    (3) With a high side float system this means that the system is charged with too much refrigerant or that the needle and seat are leaking.
    (4) Capillary tube systems have this trouble if they are charged with too much refrigerant.
11. In the low pressure side on the S.S.V.
12. In the high pressure side on the D.S.V.
13. To prevent a flow of air into the system or of gas out of the system.
14. Approximately 10 psig because the refrigerant will be at 5 F.
15. Approximately 125 psig.
16. The precautions are:
    (1) The charging line must be in excellent condition.
    (2) One should wear goggles.
    (3) The charging line should be purged.
    (4) Only the specified amount should be added to the cylinder (85 per cent full).
17. Because the valve stem controls two different openings.

18. The four common expansion valve troubles are:
    (1) Leaking needle.
    (2) Out of adjustment.
    (3) Moisture on the bellows.
    (4) Moisture at the needle.
19. This moisture will freeze and prevent any movement of the bellows keeping it open continuously or closed almost continuously.
20. Immerse the float ball in very hot water and watch for bubbles.
21. Pass a swab saturated with 28 per cent acqua ammonia around the joints (do not touch any parts) and watch for white fumes which indicate the presence of sulphur dioxide fumes.
22. Pass the suction tube of the lighted halide torch close to the connections suspected of leaking and if the flame becomes a brillian green a leak is present (use the torch only in a well ventilated place).
23. A higher-than-normal head pressure.
24. The two methods are:
    (1) Balancing the pressure in the crankcase and adding the oil through the oil plug opening.
    (2) By sucking the oil in through the S.S.V. gauge opening.
25. To remove all the refrigerant from the oil by purging this gas out of the D.S.V. gauge opening.

12-34. ANSWERS TO REVIEW QUESTIONS

1. The refrigerant must be chemically pure or acids and/or abrasives will be formed that will harm the system.
2. They are stored under pressure and any sudden release may put a freezing liquid on one's face, shin, or eyes.
3. A cheap or old, or corroded cylinder may explode at any moment, causingserious damage.
4. Glycerine is a non-corrosive chemical.
5. The two types of refrigeration service shops are (1) the shop that repairs equipment for one company; (2) the shop that overhauls equipment for any and all service men that wish to use its facilities.
6. A lathe may be used for the following work:
    (1) To true up shafts including crankshafts and armatures.
    (2) To reface armatures commutators.
    (3) To reface valve seats.
    (4) To reface crankcase seal disks and sylphon bellows rings.
    (5) To open liquid receivers.
    (6) To wind tubing into cylindrical forms.
    (7) To grind crankshaft seal shoulders.
7. Two types of charging stands being used at the present time are:
    (1) Dispensing the refrigerant directly from the stored cylinder into the service cylinders and determining the amount transferred by weighing the cylinder into which the refrigerant is transferred.
    (2) The other stand uses an intermediate cylinder equipped with a glass sight level gauge. The refrigerant is removed from this intermediate cylinder into the drum to be charged and the change in the liquid level in the sight level gauge indicates the amount transferred.

8. An air dryer is necessary in the inlet of the air compressor to enable the obtaining of dry high pressure air. If this dryer is not used, moisture condensation gradually accumulates in the air storage tank and eventually the compressed air is made unsuitable for blowing out parts of the refrigerating system.
9. Three kinds of lapping blocks or surfaces are:
   a) A flat plate surfaced with fine sandpaper or polishing paper.
   b) Plate glass.
   c) Seasoned cast iron blocks with a very accurately ground and lapped flat surface.
10. A compressor should be run at its rate of speed when testing it for efficiency to obtain a true picture of how much it can pump. The volumetric efficiency of a compressor decreases as the speed increases and conversely. For this reason the only accurate test is to run the compressor at its rated speed.
11. "Baking" a compressor is to keep it at 200 F. to 250 F. for a period of 8 to 24 hours with the 24-hour period recommended. This will drive any moisture out of the compressor, leaving it thoroughly dehydrated.
12. The exhaust fan of a refrigerating repair shop is usually located near the floor because most of the refrigerants in a gaseous form are heavier than air.
13. Goggles, rubber aprons, and rubber gloves should be used when working with the acid dip bath to minimize chances of being blinded or of getting severely burned by the acid. This is a safety precaution that should always be followed.
14. The fire hazard in a paint spray booth comes from the use of thinners and nitrate paints which are explosive when very finely atomized. The paint spray booth should, therefore, be shielded from any open flames in the room and it should have a separate adequate exhaust fan to remove the paint fumes as rapidly as they are formed. The best solution to the problem is to have the paint spray booth located in a separate room.

13-9. ANSWERS TO REVIEW QUESTIONS

1. (A) is the generator during the firing periods and is the absorber during the cooling periods.
   (B) is the water-cooled condenser.
   (C) is the liquid receiver.
   (D) is the cooling coil.
   (E) is the burner.
   (F) is the cooling water inlet to the condenser.
   (G) is the cooling water outlet of the condenser.
2. The ammonia and water combination in absorption refrigeration is popular because of the availability of the two, the powerful attraction the one has for the other, the decided temperature difference in their boiling points, and the high latent heat of the ammonia.
3. The purpose of the hydrogen in the Servel is to provide about nine-tenths of the pressure in the cooling coil, permitting the ammonia to vaporize at a low vapor pressure. The total of the two pressures equals the pressure throughout the system.
4. Those localities in which electricity is not available are ideal for the use of the kerosene-

fired absorption refrigerator.

5. Michael Faraday discovered the absorption principle in 1824.
6. The absorber in the Servel cycle must be cooled because when the weak water solution absorbs the ammonia gas out of the hydrogen, heat is generated and it must be removed.
7. The purpose of a heat exchanger is to exchange heat between liquids or gases at two different temperatures. For example, the liquid line of the Servel is surrounded by the cool mixture of ammonia and hydrogen coming from the cooling coil so that the liquid ammonia will be cooled before it reaches the cooling unit.
8. When the gas flame becomes larger the percolation action increases, forcing more ammonia gas up to the condenser, more ammonia condenses, and therefore a greater quantity of liquid ammonia will be fed to the cooling coil, producing more refrigeration.
9. The storage chamber on the receiver is insulated because otherwise it would act as a cooling coil during the freezing part of the cycle and would produce too much refrigeration.
10. These mechanisms are provided with a fuse plug because ammonia is a high pressure refrigerant and during extreme cases such as a fire in the building the unit might blow up or explode if it were not provided with this fuse plug.
11. (1) Water, (2) silica-gel (3) silver chloride.
12. It depends upon the compression due to the heat in the generator and upon the heat removing ability of the condenser.
13. It acts as the absorber during the freezing part of the cycle.
14. Yes, and they are still being used on freight cars.

14-14. ANSWERS TO REVIEW QUESTIONS

1. Ammonia, hydrogen, and water are the three substances used in the Servel mechanism.
2. The F-11 is used to form a hot vapor bath around the generator during the heating period and to cool the generator during the absorption period.
3. The Faraday was equipped with a pilot light because the gas burned intermittently.
4. Copper tubing was used in the Faraday because dry or anhydrous ammonia was used as the refrigerant.
5. The Faraday water valve was operated by the temperature of the exhaust water. If the water leaving the unit became warmer, the valve opened farther and conversely.
6. The water cooled the F-11 refrigerant, which in turn cooled the absorber.
7. The temperature control valve permitted only liquid ammonia to go into the cooling coil during the generating period and maintained any desired pressure in the cooling coil during the absorption period.
8. The purpose of the methyl chloride in the secondary cooled Servel is to cool the absorber, the methyl chloride in turn being cooled by the air in the room.
9. The kerosene used in the intermittent absorption machines must be very clean and dry otherwise it will emit a smudge and odor.
10. By controlling the size of the

gas flame.

11. The upper coil is the cabinet cooling coil while the lower coil is used to produce ice cubes.
12. To permit feeding the cooling coil with liquid refrigerant.
13. Ammonia.
14. It was used to hold the condensing water, which in turn surrounded the condenser coils.

15-25. ANSWERS TO REVIEW QUESTIONS

1. The fluids flow by gravity and the unit must be level to permit proper flow.
2. Air flow is obtained by putting the cabinet at least two inches from the back wall and keeping at least 12 inches of clear space above the cabinet.
3. Yes.
4. A flue is a passage way for the products of combustion.
5. The pressure is measured with a water filled manometer.
6. The pressure regulator in the base of the cabinet is not needed for L P systems because the cylinders or bottles already are provided with regulators.
7. A thermostat controls the amount of gas fed to the burner.
8. The thermostat has a minimum flame by-pass adjustment.
9. Either heat isn't getting into the generator or the condenser and absorber are not being cooled.
10. A timer operates electric heating elements that quickly remove the frost from the cooling coil without affecting the foods being stored in the freezer compartment.

16-15. ANSWERS TO REVIEW QUESTIONS

1. A hermetic mechanism is one that has all sealed joints.
2. A static condenser.
3. It is fastened by a flash resistance welding process.
4. A motor, a rely, a thermostat, a light, and a light switch.
5. By using a separate thermostat to control the electrical flow to the resistance unit in the compartment.
6. To remove the frost without allowing a rise in temperature of the foods in the freezing compartment and in the cabinet.
7. A solenoid valve controls a bypass that carries hot compressed gas directly to the cooling coil.
8. A semi-automatic defrosting system must be manually turned on, but it automatically returns to normal operation.
9. The tubing is installed in the door jam just back of the plastic breaker plate. This design permits removing the complete unit without disconnecting any of the unit.
10. Some units drain this water to a pan near the motor-compressor and evaporate it there; others drain the water into a tray and it must be disposed of manually.

17-31. ANSWERS TO REVIEW QUESTIONS

1. No, some are completely sealed including the charging plug.
2. Freon 12 is the most popular.
3. To direct the air flow, and to reduce noise.
4. Generally one, but there are many on the market that have two, one for frozen foods and one for regular refrigerator temperature maintenance.
5. The hot oil will back into the suction line during the off part of the cycle and warm the thermostat and the cooling coil.
6. If tubing vibrates, have a har-

monic of the motor-compressor vibration. If the tubing vibrates at a frequency within the audible range an annoying sound is heard. This vibration can be eliminated by putting rubber weights on the tubing or even bending the tubing slightly.

7. The dome may be opened by grinding the welded joint, or cutting the welded joint in a lathe or in a vertical mill.
8. A vacuum cleaner with special nozzles is essential if one wishes to do a good cleaning job.
9. The compressor motor, the condenser, and the cooling coil must be fastened to a rigid frame to prevent abuse.
10. Silver brazing is recommended for all copper and steel joints.

18-30. ANSWERS TO REVIEW QUESTIONS

1. The temperatures desired in commercial refrigeration are as follows: (1) Water-cooling installations have a water temperature 40 F. to 55 F. (2) Walk-in coolers 36 F. to 40 F. (3) Florist cabinets 50 F. to 60 F. (4) Ice cream cabinets 0 F. to 12 F. The minimum temperature encountered in commercial refrigeration is for the maintenance of brick ice cream which needs a temperature of 0 F. The manufacture of ice cream in small quantities is becoming popular and in commercial installations of this type temperatures of -10 F. are desired for hardening.
2. The joints between the doors and their frames and between windows and their frames must be air-tight in refrigerator cabinets or a continuous air circulation will occur due to the temperature differences. This will increase the cost of operation.
3. The windows of the refrigerator cabinet are usually of the two or three pane construction having one and two dead air spaces respectively. The glass itself is a very poor insulator so the dead air spaces are used to provide the insulation. Theoretically, dead air is one of the best insulations, but in the case of this kind, the radiation load into the cabinet is high and the dead air spaces are so large that internal convection takes place permitting some heat to pass into the cabinet.
4. The dead air space formed by these window panes must be kept free from moisture to stop fogging or moisture precipitation on the inner pane. This is done by using a moisture absorbing chemical such as calcium chloride between the panes.
5. The lights of display counters are usually mounted outside of the cabinet because they produce considerable heat and it is therefore more economical to have them mounted outside.
6. The average temperature of a walk-in cooler may be found half way between the cold and warm air flues of a cabinet, two inches away from the wall that is farthest from the door, and about four feet from the floor.
7. Most commercial installations are of the multiple type because this permits the use of a smaller condensing unit as the peak loads of the various cabinets do not occur at the same time. With one cabinet or in a single installation the unit must be large enough to take care of the peak load.
8. (1) Water in a heat treating room of a tool and die factory should

not be cooled lower than 50 F.; 55 F. is recommended.
(2) A water temperature of 40 F. to 45 F. will be found satisfactory for an office building.

9. The length of the counter determines the number of coils because of the air circulation. The circulation must be greater in the horizontal direction than it is in the vertical direction which tends to slow it up considerably. To minimize this horizontal air circulating distance, coils are placed at both ends of the counter.
10. The moisture content in the air is very important in produce storage cabinets because most of the material stored has a very high moisture content. If the air in the cabinet is dry this dry air as it circulates over the material will remove some of the moisture from them, spoiling the appearance and decreasing the weight of the material.
11. Vertical double glass or triple glass plates are built around the upper third of the cabinet.
12. A double duty case is one that is used as a display case and as a refrigerator cabinet in the base.
13. The cooling coil is located in the base in the back of the case.
14. These coils are defrosted with hot condenser gas or with electrical heating coils.
15. The two basic types are the ice cube tray type and the automatic ice cube maker.
16. Hot gas defrosting is by-passing the condenser gas directly into coils in the cooling compartment.
17. The water pump is to push cooling water forcibly around the milk cans.
18. The bacteria growth in unpasteurized milk is very rapid if it is kept at a warm temperature.
19. It is very compact.
20. To sub-cool metals in heat treating and to cool electrode points in spot welding.

19-57. ANSWERS TO REVIEW QUESTIONS

1. The advantage of a non-frosting cooling coil is that it maintains a constant heat removing efficiency without needing any attention; and its operation is such that it does not remove the moisture from the air very rapidly, permitting a higher relative humidity to be maintained in the cabinet.
2. A high pressure motor cut-out switch should be installed on all water-cooled condensing units because of the danger of an inadequate water supply. If the water were to be restricted in its flow, the resulting excessive head pressure would soon burn out the motor unless the safety cut-out functions.
3. Intake valves of a compressor are frequently located in the head of the piston, although some companies locate them in a valve plate, while others use valve ports cut into the cylinder walls.
4. It is advisable to connect the high pressure motor cut-out bellows to the cylinder head of the compressor because this facilitates the removal of the valve for servicing.
5. The three types of water valves are: (1) the electrically operated type, (2) the pressure operated type, (3) the thermostatic type.
6. (1) The metering, two-temperature valve; (2) the snap-action, two-temperature valve; (3) the thermostatic, two-temperature valve.
7. The advantage of a water-cooled

condenser over an air-cooled condenser is that it enables lower head pressures thus permitting greater capacity and reducing the wear on the moving parts of the system. Another advantage is that the condensing unit may be installed in small, out-of-the-way corners without decreasing its efficiency. However, the use of water means an additional expense of operation and occasionally localities are found wherein the water is corrosive to the water-carrying tubes. The advantage of the air-cooled condenser is that it is a simpler mechanism, has a cheaper first cost, allows for an easy installation, and may be used anywhere that sufficient air is available. The disadvantages are that the room in which the condensing unit is installed must be of sufficient size to provide enough air for cooling, the fan produces some noise, and because of the higher temperature of the cooling medium, the head pressure in the system is greater which reduces its capacity.

8. The forced circulation cooling coil takes up little space, needs no baffles, and cools the produce very rapidly.
9. To enable one motor control to control the cooling of all the coils connected in that system.
10. The check valves are located in the suction lines of the coldest coils.
11. The coils controlled by the two-temperature valve should not exceed 40 per cent of the total refrigeration load.
12. The evaporative condenser saves 85 per cent of the water because it uses latent heat of evaporation for water instead of the specific heat (1000 Btu) lb. vs. 1 Btu 1 lb).
13. Yes, these safety devices are required by code and the safety opening is piped to the outdoors through a silver brazed pipe.
14. Water.
15. To carry heat between the refrigerant coil and the beverage coil.
16. The refrigerant flows in the opposite direction to the water flow. This action places the cold water near the coolest refrigerant and thereby maintains a more constant temperature difference.
17. The air-cooled condenser is used only during normal loads; this action conserves water.
18. They must be cleaned to remove odor producing elements.
19. The water is sprayed on, or dripped on the external surfaces of the coil, thus melting the ice accumulation.
20. These drain facilities must be kept warm to prevent the drain water from freezing in them and clogging them.
21. The two check valves are used (1) to prevent refrigerant from by-passing the automatic expansion valve and to permit by-passing the thermostatic expansion valve.
22. The current requirements for the larger motors is too much for the small accurate contacts of the standard motor control.
23. The separator is insulated to prevent condensation of refrigerant in it.
24. The return refrigerant is heated to prevent slugs of liquid refrigerant from reaching the compressor and damaging it.
25. The electric water valve.
26. To control the amount of make-up water needed to replace the water evaporated.
27. No, because it never frosts and

if it did, it would defrost each cycle.

28. The surge tank is a gas storage cylinder and it increases the cycling intervals of a system.
29. A sweet water bath is a beverage cooling device using tap water as a brine.
30. The vibration dampers are installed in both the suction and liquid lines as near to the condensing unit as possible. They are used to reduce noise from vibration.

20-57. ANSWERS TO REVIEW QUESTIONS

1. Code installations require relief valves be installed in liquid receivers because it is believed that this construction will prevent accidents and explosions.
2. Hand valves are provided in the refrigerant lines leading to each individual coil to facilitate servicing and to permit disconnecting that coil in case of accident.
3. It is recommended that tubing be run parallel with beams rather than across them to give additional protection.
4. It is absolutely necessary to mount a float valve level in order to permit the float to operate correctly. If not in a level position, the float will be out of calibration and cannot function properly.
5. Two-temperature valves are usually located on the manifold wall boards.
6. Soft tubing may be used near the condensing unit and near the cooling coil. It is not to exceed six (6) feet in length.
7. After assembling a dry multiple coil system, it is necessary to remove the air and other foreign substances within the coils and the lines. To do this, one should close all the hand valves except the liquid line hand valve for one coil. The suction line of this same coil should be left loose at the hand valve and the liquid receiver valve cracked. The surge of a small quantity of the gas will force the air out of this loose connection and after one detects the odor of the refrigerant, the joint is tightened and the valves closed. Repeat this for each coil until all the coils have been purged. This will remove all the air from the installation except from the main suction line. This main suction line may now be purged by leaving the connection at the compressor loose and purging the gas through one of the coils down the suction line and out of the loose connection. With all connections tight and all the hand valves open and with the liquid receiver valve shut a vacuum should now be drawn on the installed part of the system. The gas evacuated is discharged out the compressor discharge service valve, it being turned all the way in. If the gas is irritant, a neutralizer will have to be used here to eliminate the annoying odor. The machine may now be started, opening one coil at a time and allowing 15 minutes between each coil to reduce the starting load on the condensing unit.
8. Under normal conditions it is necessary to put a dehydrator in the system because all the parts installed have been exposed to the air which means they must be dehydrated thoroughly.
9. The purpose of a dehydrator in the suction line is to positively insure that no moisture can reach

the compressor.

10. Hard drawn copper tubing and streamlined fittings are becoming popular because of the rapidity with which they may be installed and because tubing of this type may be obtained in sizes much larger than is obtainable in the soft copper.
11. The indication of a lack of refrigerant in a multiple low side float system is a continuous hissing sound in the most remote coil along with a relatively warm liquid inlet connection.
12. The troubles which may result in a coil frosting excessively at the valve but being dry at the other extreme are: (1) Partially clogged screen; (2) lack of refrigerant in a thermostatic element if it is a fairly warm coil; (3) power bulb located too close to the coil; (4) moisture on the bellows.
13. (1) By using a rubber seal, (2) by using a drilled frost-proof unit, (3) by shellacking the joint between the nut and the tubing.
14. The open drain is to prevent water being syphoned back into the fresh water lines in case of a sudden pressure change.
15. If a multiple system is running under a 5 in. vacuum the system must be stopped to permit the low side pressure to build up to 0 psi before a coil can be removed from the system. That is, (1) remove the refrigerant from that system to be opened by closing the liquid line valve; (2) permit the compressor to run until that part of the system becomes warm, indicating that all the refrigerant has been removed; (3) stop the compressor for a few minutes until the compressor pressure reaches 0 psi; (4) shut off the suction line valve which controls that part of the system to be opened.
16. Service men should follow a practice whereby the upright charging cylinder is fastened to the suction service valve in the system and then very carefully heated to drive the gas from it into the system.
17. The four most important safety precautions to be observed when charging a system through the low side are: (1) Be very sure that the flares on the charging tubing are in excellent condition. (2) Do not heat the service drum any warmer than is comfortable to the hand. (3) Mount the refrigerant drum securely thereby eliminating any accidental twist or sudden strain on the charging tubing. (4) Wear goggles.
18. Flange fittings soldered to the tube and to the coil is an excellent method of making connections inside a cabinet. This practice permits an easily dismantled connection and it is frost-proof. Either paper or lead gaskets may be used between the two flanges while Monel or heavy cadmium plated bolts must be used to fasten the flange shoulders together.
19. The purpose of felts and fine mesh screens in a dehydrator is to insure that none of the moisture absorbing substance will circulate through the system and to trap any solid particles that may be circulating in the system.
20. The system should be very carefully checked for leaks if a lack of refrigerant is discovered, because under normal conditions it takes 5 to 10 years before the refrigerant can leak out the small undetected crevices. It is a waste of refrigerant and of time to simply charge the system with

refrigerant. A conscientious service man will spend time required to locate leaks.

21. A dehydrator removes moisture while a neutralizer reduces the acidity of the refrigerant.
22. (1) Not to buckle it. (2) To provide for adequate oil return to the compressor.
23. If left in an open container it will soon become saturated with moisture and be useless.
24. Small quantities of methanol alcohol.
25. (1) Poor motor control. (2) Lack of water. (3) Air in the system.

21-59. ANSWERS TO REVIEW QUESTIONS

1. A Btu is the amount of heat required to change the temperature of 1 pound of water 1 F.
2. 2545.6 Btu per hour equals 1 H.P.
3. Sensible heat is heat which causes a change of temperature.
4. Latent heat causes a change of state.
5. Specific heat of a substance is the heat required to change the temperature of 1 pound of that substance 1 F.
6. The use to which the cabinet is put determines to a considerable extent the usage heat load.
7. This is a common calculating basis, easy to measure, and experiments point to it as the most accurate surface to use.
8. To promote air circulation in a cabinet.
9. To prevent a heat transfer from the cold air coming from the coils to the warm air going to the coils.
10. Spruce or fir wood.
11. To give adequate refrigeration during rush periods.
12. The ice pressure would burst the container.
13. .45 Btu per pound.
14. At 0 F.
15. 6 pounds per gallon.
16. The temperature of the gas becomes 10 F. to 12 F. warmer than the refrigerant temperature in the coil.
17. The effective latent heat is the actual amount of heat removed from the cabinet for each pound of refrigerant evaporated, while latent heat is the total amount of heat absorbed by the refrigerant but part of which is used to cool its own liquid down to the evaporating temperature.
18. The addition of heat due to compression.
19. Because all energy units are mutually convertible. The mechanical energy of the motor produces heat energy.
20. Volumetric efficiency is the amount of gas actually pumped per revolution of the compressor divided by the piston displacement of the compressor. It is effected by the speed, the valve design, the piston clearance, the head clearance, the compression ratio, etc.
21. The size of unit, the compactness desired, the kind of unit, the locality, etc.
22. Motor efficiency is the ratio of the mechanical power output to the electrical power input and it varies between 50 per cent and 90 per cent depending on the size of the motor.
23. (1) Heat travels from the food to the air with difficulty.
    (2) Heat travels from the air to the coil with difficulty.
    (3) Heat travels through the coil metal very efficiently.
    (4) Heat travels through the oil film with some difficulty.
    (5) Heat travels into the refrigerant with ease.

22-30. ANSWERS TO REVIEW QUESTIONS

1. The first scientific air conditioning machine was installed in 1901.
2. Dr. Willis Carrier is known as the "father" of air conditioning.
3. A complete air conditioning system must control the temperature, the humidity, the air cleanliness, and the air movement.
4. Air conditioning is as important in many industrial processes as it is for human comfort.
5. The atmosphere is composed of nitrogen, oxygen, monatomic gases, carbon dioxide, hydrogen, water vapor and impurities.
6. Water exists in the invisible water vapor (gas) form.
7. Fog is condensed water vapor in the air. It exists as extremely small droplets of water.
8. A grain is a unit of weight. 7000 grains equal one pound.
9. A micron is 1/1000 of a millimeter or 1/25400 of an inch.
10. One should know the dry bulb temperature and the wet bulb temperature.
11. Psychrometry is the science of air mixtures.
12. A rapid air movement causes a feeling of lower temperatures and no air movement causes a feeling of stuffiness.
13. The boiling temperature of water at 1 in. hg. is 79 F.
14. Moisture may be removed from the air by condensation or by chemcial absorption (silica gel).
15. As the air temperature decreases, it is able to absorb less and less moisture (at lower temperatures, the vapor pressure decreases).
16. A psychrometer should be used with clean water, a white wick, considerable air velocity and with a minimum of radiation sources.
17. The values that are constant along the horizontal line of a psychrometric chart are (1) vapor pressure (2) grains of moisture (3) dew point temperature.
18. Yes, the air contains water vapor at temperatures below 32 F.
19. If a certain sample of air is heated, the relative humidity decreases. At the average temperatures, the relative humidity will decrease by one half for each 20 F. rise in temperature.
20. Most people are comfortable in the summer while in air movement of 20 ft./min. and between 72 F. db -- 100% rh and 85 F. db and 10% rh.
21. Air ducts are used to deliver conditioned air, to return air to the conditioner, and to feed fresh air to the conditioner.
22. The purpose of a grille is to prevent articles being put in the ducts and to control the air flow at the duct openings.
23. Dust particles vary in size from .1 to as large as 100 microns in diameter.
24. Fumes are solids that are formed by solidification of vapors injected into the atmosphere.
25. A vapor is a gas near its liquefication temperature and pressure or in the presence of its liquid. A gas is considerably above its liquefication temperature and pressure condition (superheated).
26. Oil removes impurities from air by adhering to the solid particles as they come in contact with the oil covered fibers.
27. Ultra-violet rays have the ability to destroy micro-organisms (bacteria) in the air.
28. A cooling coil cleans the air because the moisture condensed

on it removes dirt particles from the air as the air passes over the coil.

29. Organic gases are absorbed by the activated charcoal.
30. Electricity is used to ionize the space in an air duct and the ionized particles are attracted to plates of opposite polarity thus cleaning the air.

23-25. ANSWERS TO REVIEW QUESTIONS

1. Air does have weight. It weighs approximately .074 lbs. cu. ft. at 70 F.
2. The specific heat of air varies. It is .24 Btu/lbs. under normal conditions.
3. Air is used to heat, to cool, and to ventilate.
4. Moving air causes vibrations; some of these vibrations can be heard, especially if the air does not flow smoothly.
5. It must move more than 25 feet per minute.
6. The circular duct carries more air per amount of duct material used.
7. The axial flow and the radial flow fans.
8. A pressure difference produces an air flow.
9. The air has weight, and it takes extra energy to make it change direction.
10. The air flow is improved by using vanes.
11. To insure that each outlet receives its correct amount of air.
12. The pressures are so small that bourdon tube gauges and mercury filled manometers are not accurate enough.
13. A differential manometer measures the difference between two varying pressures.
14. The velocity pressure is the difference between the total pressure and the static pressure.
15. Several readings must be taken in carefully selected places in a duct to obtain an accurate average velocity.
16. Air turbulence is air moving in a direction different from the direction it is being directed.
17. Air stratification is when air is not moving and assumes different levels based on its temperature (density).
18. Ducts may be made of tinned sheet metal, galvanized sheet metal, sound absorbing non-metallic material and wood.
19. If the resistance to air flow is equal to each outlet, each outlet will receive its proper amount of air.
20. Air noise can be reduced by reducing air velocities, by using smoother ducts, by using sound absorbent material, by insulating the duct from any part of the building, and by placing a flexible coupling or section in the duct especially near the machinery.

24-20. ANSWERS TO REVIEW QUESTIONS

1. The main parts of the heating load are heat leakage and infiltration.
2. The main sources of heat are the heat leakage, the infiltration, the sun load, and heat from occupants and appliances.
3. The variables are area, temperature difference, the U facts, and the time.
4. The window dimensions are chosen as the size of the frame opening in the wall, not just the glass area.
5. No, because the coldest recorded temperatures do not last long enough to make that size plant

necessary, and also the equipment has sufficient reserve to handle this extra load for the short time it occurs.

6. They are considered part of the room.
7. The temperature is usually assumed to be half way between the design ambient and indoor temperature.
8. Infiltration is air that leaks into a building and exfiltration is air that leaks out.
9. The positive pressure method is to use a separate fresh air intake, condition this air, and free the air into the house. Therefore, air will leak out through the cracks in the house.
10. The east, south, and west walls only are effected by the sun.
11. The sun's heat is usually taken into consideration by adding 15 F. to the design temperature.
12. No, the heat from the sun penetrates the windows immediately, but there is a 3 hour time lag for the heat to get through the wall.
13. Heat lag in a building is that time it takes to heat the structure of the building.
14. The insulating ability of one sheet of aluminum is poor on conductivity, poor on convection, fair on radiation. However, several layers of aluminum foil give excellent results on one layer of aluminum and some bulk insulating material.
15. An air film is a very thin layer of stale air that clings to all surfaces. This air film allows about 1.16 Btu/F/hr/sq.ft./hr.

25-27. ANSWERS TO REVIEW QUESTIONS

1. Three types of air conditioning plants are the complete system located remotely with ducts used to deliver the air; the system with the mechanism located in the basement and the coils located in a cabinet in the room; and the self-contained unit.
2. Remote units use the thermostatic expansion valve while the self-contained units use the capillary tube.
3. Solenoid valves are used to stop the flow of refrigerant mainly to prevent flooding and frosting conditions.
4. The most economical way to use electricity is to use a heat pump.
5. A by-pass system conditions some of the air recirculated while some of it is unheated. The two are then mixed and delivered to the room.
6. The four most common sources of energy are coal, oil, gas and electricity.
7. The heating value of bituminous coal is approximately 14000 Btu/pd.
8. The three types of oil burners are the pot type, the rotary type, and the gun type.
9. The main advantage of gas as a fuel is that it is already a gas and it contains very few non-combustible solids.
10. The stack temperature must be kept at 300 F. or higher to prevent contaminant condensation.
11. The air as it leaves the cooling coil has 100% humidity.
12. Yes, chemicals can be used to absorb moisture from the air; calcium chloride, silica gel, and/or activated aluminum.
13. The condensate is drained to the condenser and motor-compressor and helps cool them.
14. Outside air is brought into the unit by means of a duct.
15. A bi-metal thermostat is an electrical switch operated by a

double metal strip that moves as the temperature changes.

26-18. ANSWERS TO REVIEW QUESTIONS

1. The condenser.
2. Lord Kelvin.
3. Two; the condenser and the cooling coil.
4. By evaporating the refrigerant in the outdoor coil at -10 F. or -20 F.
5. The heating cycle and the cooling cycle.
6. When the outdoor temperature and the indoor desired temperature are close together.
7. The ratio of the electrical energy imprint (heat of compression) to the heat picked up or discharged by the heat transfer units.
8. It is three to six times more expensive to heat with electrical resistors.
9. 3410 Btu/hr.
10. The air coils become very inefficient at low temperatures. The well coil involves considerable just cost. The ground coil cost is high. The lake coil is limited in its accessability.
11. There are four; the air coil, the well coil, the ground coil and the lake coil.
12. A forced convection finned coil.
13. An air coil with any one of the other three.
14. The capillary tube works equally well when the refrigerant flow is reversed through it.
15. The three way valve can direct the refrigerant flow to either the indoor coil or outdoor coil. Also it can direct the flow from either the inside coil or outside coil to the compressor.

27-20. ANSWERS TO REVIEW QUESTIONS

1. The heat load increases.
2. They are driven by V-belts.
3. The condenser is mounted just in front of the car radiator.
4. Silver brazed joints are used except where servicing may require disconnecting, and at these places the standard flare connection is used.
5. Yes, they all have provisions for installing gauges.
6. A D.C. motor is used.
7. The air distribution is difficult because of the low ceiling and seat obstructions.
8. Yes, they are provided with a fresh air intake.
9. About five to eight tons.
10. Average 2 to 3 H.P. As much as 8 H.P. under the most severe conditions.
11. Rapid changes in compressor speed may cause liquid refrigerant slugging.
12. On remote units both the automatic expansion valve and the thermostatic expansion valve have been used.
13. The cooling coil is usually mounted just back of the back seat, or under the instrument panel.
14. The maze-type, oil washed, disposable filter is usually used.
15. They operate at a higher speed than the engine to insure more capacity at engine idling speeds.

28-52. ANSWERS TO REVIEW QUESTIONS

1. The frozen process keeps the food at its maximum taste, aroma, and texture.
2. In Springfield, Mass., 1930, the Birdseye Company was the first to freeze food directly for the consumer.
3. Enzymes are the cause of food spoilage as they encourage or accelerate food spoilage.

4. One of the most popular modern insulations is spun glass or Fiberglas.
5. The steps used to prepare vegetables for freezing are:
   a. Clean and trim.
   b. Blanche in boiling water.
   c. Cool.
   d. Package in moisture-proof material.
   e. Freeze as quickly as possible.
6. Hermetic insulation is insulation sealed against moisture and air.
7. The two most common frozen foods cabinet refrigerant controls are the capillary tube and the thermostatic expansion valve.
8. A frozen foods cabinet should be defrosted about each six (6) months.
9. Most 6 cubic foot volume frozen foods cabinets use a hermetic condensing unit.
10. Freezer burn is caused by dehydration of the surface of unsealed frozen foods and by oxidation of the food.
11. Beef may be safely stored for 6 months at 0 F.
12. The best temperature range for frozen foods cabinets is 0 F. to -10 F.
13. Most frozen food cabinets use a thermostatic motor control.
14. It is essential to allow free air circulation around a frozen foods cabinet to allow proper cooling of the condensing unit.
15. Ice accumulation in the insulation is probably the most serious as it will ruin the cabinet in addition to causing poor frozen foods temperatures.
16. All oils have a quantity of wax in them, and the extremely low temperature encountered in a frozen foods unit sometimes causes a slow separation of the wax out of the oil.
17. Moisture may get into a refrigerating system from moisture laden refrigerant, from moisture laden oil, from careless service procedures allowing moisture laden air into the system, and finally, a leak in the system when that part is operating at below atmospheric pressure.
18. Moisture is easily and very thoroughly removed from a system by using a good, adequately sized dehydrator.
19. External service jobs may be done on a hermetic system on the premises, i.e., replacing the motor control, the relay, the fan motor, etc., but any internal troubles must be remedied in a thoroughly equipped overhaul shop.

INDEX

INDEX

N

O

P